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THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

Vol. XI December, 1922 No. 6

Chronicle and Comment

The Chicago Service Meeting

THE annual Chicago Meeting of the Society will be held Jan. 31, 1923, during Show Week. Automotive service will be the dominant topic at the technical sessions and the dinner. This meeting will be especially valuable to factory and dealer service-managers and operators of large fleets of vehicles. Further details will be found on p. 552.

The Production Men

THERE are many members of the Society who should be "past masters" in production. There are wonderful brains behind some of the factories that are in production in a large way. These men have very superior knowledge. I hope that the best production men in the United States will tell the Society what should be done along production lines.—Charles W. Nash.

Standardization

STANDARDIZATION by one firm to suit its particular purposes and convenience is a simple affair and a quick process. Industrial standardization requires that the needs of industry be unified with the least possible disturbance. Recommendations and conclusions must be sound and economical and conform generally to the practice of the manufacturer, as well as meet the requirements of the buyer. Otherwise nothing but failure can result.—D. R. MacDonald.

The Annual Meeting

THE Annual Meeting of the Society will be held in New York City, Jan. 9 to 12, 1923, during the week of the National Automobile Show. A number of technical sessions, the Annual Business Meeting and the Standards Committee Meeting will be conducted during this period in the Engineering Societies Building. The Annual Dinner has been set for the evening of Jan. 11 at the Hotel Pennsylvania. Tentative details of the program and a dinner reservation blank are given on p. 551. A *Meetings Bulletin* will reach the members about Dec. 15 with the complete and final announcement.

Future Standardization Work

ON p. 555 of this issue will be found a resume of the work of the Standards Committee for 1922 and a list of subjects that will be considered during the coming year. In the majority of instances Subdivisions are appointed to formulate tentative recommendations covering subjects assigned to the various Divisions of the Standards Committee. Non-members of the Standards Committee, as well as non-members of the Society, are serving on these Subdivisions as it is the purpose of the Society to have all interests represented in the standardization work carried on by it for the automotive industries. Anyone interested in particular subjects is at all times invited to communicate with the Subdivisions through the Society in order that assistance may be rendered while the work is in the formative period.

Oil-Pumping

THERE are many contributory causes of the service trouble familiarly known as oil-pumping. Any one, several or all of them may result in excessive passage of oil to the combustion-chamber. Piston design and clearance, ring width and form, crankshaft oil-hole location, oil-pressure intensity and many other factors affecting this bugbear of the service-man are discussed in this issue of THE JOURNAL. The volume of experience related by the several engineers is evidence of a general and diligent study of the problem. Numerous remedies are suggested but it is noteworthy that no single solution is agreed upon. Apparently oil-pumping can be forestalled only by careful elimination of all the contributory causes, by a combination of refined design, selected clearances and good workmanship. The effect of wear can be anticipated in the original design so that conditions causing oil-pumping will not develop or can be easily controlled in service. Read the matter on p. 491.

Potential Profits

ON p. 529 of this issue will be found the various recommendations of the Divisions of the Standards Committee that will be acted upon at the Annual Meeting in January. Each of these recommendations represents a potential saving or profit that can be realized only through the actual adoption of it in future automotive practice.

There is no question that a standard which meets the approval of the qualified engineers of the industries affected will be adopted as changes in design and production permit.

Each Society member should therefore see that the recommendations of the Divisions are referred to the engi-

neering and production departments of his company in order that any desirable changes in the recommendations may be considered at the Annual Meeting. The responsibility of approving these recommendations rests with every qualified member of the Society who should, if possible, attend the meeting of the Standards Committee on Jan. 9, and participate in the discussion, or else submit comments in writing.

Only a small amount of time and expense is thus required of an individual member to make possible a potential saving of hundreds of thousands of dollars.

1923 Roster

A LARGE volume of detail work is involved in the preparation annually of the Membership Roster. The first step is the recording of changes of position and address of members. The members are urged strongly to return promptly, properly filled-in, the blanks that have been sent them this month, whether or not their address or position has changed recently. To produce a satisfactory printed roster, adequate cooperation of the members is essential.

The classification printed on the back of the blank sent to the members is an important feature, and every member is earnestly asked to supply thereon the information called for. About one-half of the members have returned similar blanks sent out in September. No additional classification forms will be mailed to the members prior to the issuance of the 1923 Roster.

It has been directed by the Council that the Roster be sent to only those members who request copies of it in advance of printing. A very small surplus stock is carried at the Society offices, and a charge of 50 cents per copy will be made for Rosters ordered by members after Feb. 15. Such orders will be filled until the supply is exhausted.

It is expected that the 1923 Roster will be issued early next spring.

S. A. E. Employment Service

THE scope of the Employment Service mailing list has been extended to include approximately 1000 employers engaged in different fields of the automotive industry, including those of the passenger-car, motor-truck, bus, tractor, motorcycle, cab, aircraft, motorboat, engine, body-building, and miscellaneous parts. Better results are being obtained in the service at less expense.

By the use of a selector addressing-machine it is possible to address quickly Men Available notices to prospective employers in any one or more of the fields mentioned. When a member registers for employment he is requested to designate the types of employer to whom he wishes notice of his availability sent. The bulletin in which his notice is printed is sent only to those in the classes specified by him. Also, the list of men available has been classified so that, when there is an opening in any given line of work, only those members who are apparently qualified to fill it are notified.

During the last half-year the Society has, it is definitely known, been instrumental in securing for 86 members positions as draftsmen, engineers, chief engineers, body designers, factory managers, sales managers, salesmen, production managers and general managers. It is believed that many others have secured positions either directly or indirectly through the S.A.E. Employment Service.

Aluminum Connecting-Rods

THE aluminum-alloy piston is rapidly gaining ground as standard equipment in passenger-car engines. It is apparent that the serious troubles encountered with the first aluminum pistons have been overcome. Radical changes have been effected in piston design; the alloys have reached a higher stage of development; special heat-treatment is producing a hardness approaching that of cast iron. This persistent development, in the face of the condemnatory experience of the pioneer users, has been stimulated by one fundamental consideration, namely, the inherent advantage of decreasing reciprocating weight in high-speed engines. The success achieved by the aluminum piston and the resulting improvement in the performance of engines equipped with it have led logically to the production of lighter connecting-rods.

One or two car companies are now using aluminum-alloy connecting-rods in their production models. The commercial practicability of forged aluminum connecting-rods is being studied to-day by many engine designers. The current interest in this latest progression of automotive design lends significance to the publication of the paper by L. H. Pomeroy on page 508 of this issue of THE JOURNAL. In it will be found a careful treatment of the fundamental reasons underlying the advantages of the forged-aluminum connecting-rod. Valuable recommendations and data relating to design are presented.

S. A. E. Handbooks

MEMBERS have probably found that since the insertion of the August 1922 issue of data sheets, their S.A.E. HANDBOOKS are rather larger than is convenient for use with 1-in.-ring leather binders, for the August issue has brought the total number of data sheets up to 188 which is really more than can be conveniently used in the standard binder.

If members desire to break their S.A.E. HANDBOOKS into two parts, this can be done readily by transferring Sections D to K inclusive to another binder, the first binder then being marked, "Vol. I, Sections A to C," and the second, "Vol. I, Sections D to K." Additional binders stamped in this way can be obtained from the Society at $4 each. If the first binder used is returned when the second is ordered, the letters indicating the Sections it is to contain will be stamped on it.

It should be borne in mind also that the Contents are arranged so as to aid members in limiting their S.A.E. HANDBOOK to only those pages that are of particular interest to them respectively, the standards being classified according to the automotive industries to which they apply by a system of key letters. Members interested, for instance, in only tractor engineering may want to retain in their books only those standards which are followed by the letter *T* in the Contents. The standards in the S.A.E. HANDBOOK may therefore be considered as being classified in the Contents in two ways; by parts and materials, such as powerplant and electrical equipment, the classifications being denoted by letters prefixed to the page numbers; and by automotive industries, the industries being denoted by letters appearing in the right-hand column in the Contents.

Ford Engine-Cylinder Production

By P. E. Haglund[1] and I. B. Scofield[1]

Detroit Production Meeting Paper *Illustrated with* Photographs and Diagrams

THE authors state the principles governing intensive quantity-production and describe the sources and methods of handling the basic materials that compose the Ford engine-cylinder. The fundamental plan of the River Rouge plant is outlined, illustrations being used to supplement the text that explains the reasons governing the location of the various units of the plant. Details are given of the use made of conveyors with the idea of keeping everything moving.

The relation of the blast furnace and coke ovens to the engine cylinder are commented upon, the power-house and foundry are described, and the production of the cylinder is set forth step by step.

THE Ford Motor Co. began making its own cylinder-block in 1907, accepting the men and methods of the day. Its foundry at that time was located at Romeo, Mich., 60 to 70 miles north of Detroit. The design of the cylinder-block has changed somewhat from the one then produced, but it will suffice, for a rough comparison, in contrasting the results of the old methods with those resulting from a greatly increased production.

In 1908, we cast 50 cylinders per day; now we are producing 8000 cylinders in 16 hr. This greatly increased production is possible only with modern methods in which the conveyor plays the most important part. If you are in the least acquainted with foundry work, try to imagine what it would mean to cast 8000 cylinders on the floor by the old methods. This would seem nearly impossible, especially from the standpoint of the iron-handling problem. It would require acres of ground, the labor cost would be multiplied four or five times and working conditions would be unbearable because of the intense smoke and gas escaping from the molds. This immense foundry production represents the ultimate result of applying Mr. Ford's ideal of producing at the minimum cost.

To market cars in such unusual quantities, it was evident that automobiles had to be produced at a lower figure. This could not be done by lowering the men's wages and driving them, but had to be done by improving manufacturing methods. With this idea in mind, every economy was effected. First, the work and the material were brought directly to the men, thus minimizing wasteful transportation of material from one part of the shop to another. This was a severe blow at high labor cost, which is the principal item in manufacturing costs.

The next step, and the most difficult one, was to decrease the cost of the materials used. It demanded that the manufacturer have control over the raw materials from nature's source of supply to the finished product. Although this could not be accomplished at once, progress has been made in the right direction.

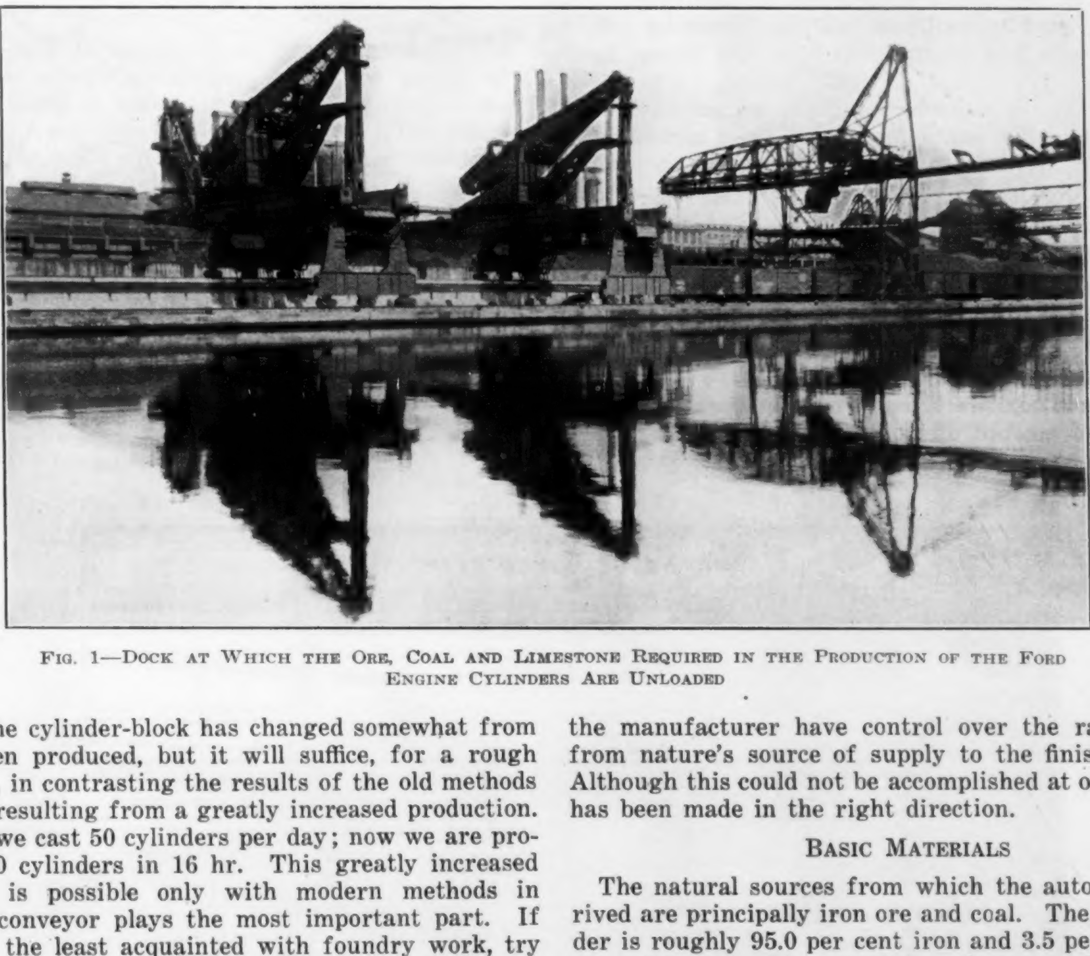

Fig. 1—Dock at Which the Ore, Coal and Limestone Required in the Production of the Ford Engine Cylinders Are Unloaded

Basic Materials

The natural sources from which the automobile is derived are principally iron ore and coal. The engine cylinder is roughly 95.0 per cent iron and 3.5 per cent carbon from the coal. The remaining elements of its composition are also derived from the ore, with the exception of possibly some sulphur from the coke used.

As yet, the Ford company does not mine all its iron ore, but a good portion of it comes from the Ford-Imperial mine, in the upper peninsula of Michigan. It is loaded into railroad cars, transported to a Lake port and

[1]Production department, Ford Motor Co., Detroit.

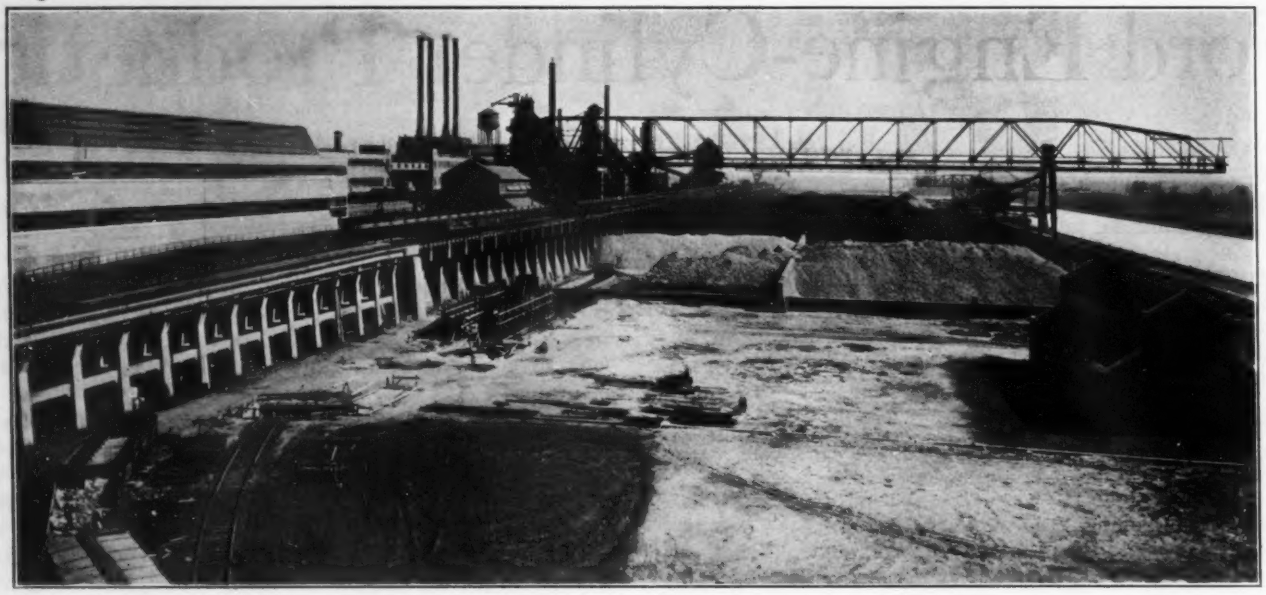

Fig. 2—The Raw-Material Storage Bins Have a Capacity of 2,000,000 Tons and Are Served by Two 550-Ft. Transfer Bridges

conveyed directly to the blast furnace by a water route, the most economical means of transportation at present. The coal is mined in the Ford mines in Kentucky. It is then transported by rail and boat, or direct by rail, to the coke ovens and blast furnace at the River Rouge plant.

Fig. 1 shows the unloading docks to which the ore, coal and limestone-laden boats are moored upon arrival at the River Rouge plant. Two Hulett ore-unloaders are shown at the left, and a Mead-Morrison coal-unloader at the right. These huge machines transfer the raw materials direct to the storage bins behind them. The bins, illustrated in Fig. 2, have a storage capacity of 2,000,000 tons, and are traversed by two transfer bridges each 550 ft. long. These transfer bridges, one of which is shown clearly in Fig. 2, transport to the various plant units coal, ore and limestone as they are needed.

Both ore and coal are brought to their destination with the minimum amount of loading, reloading or handling. This system also effects a considerable economy by elim-

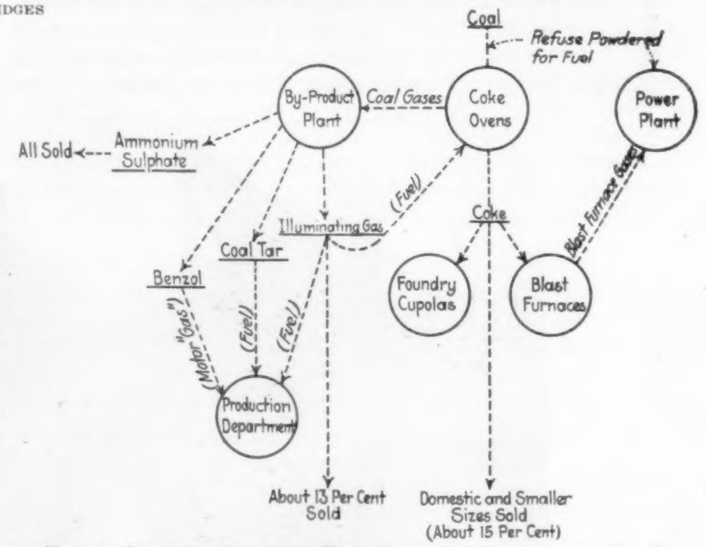

Fig. 4—Diagram Showing How Completely Coal and Its By-Products Are Utilized

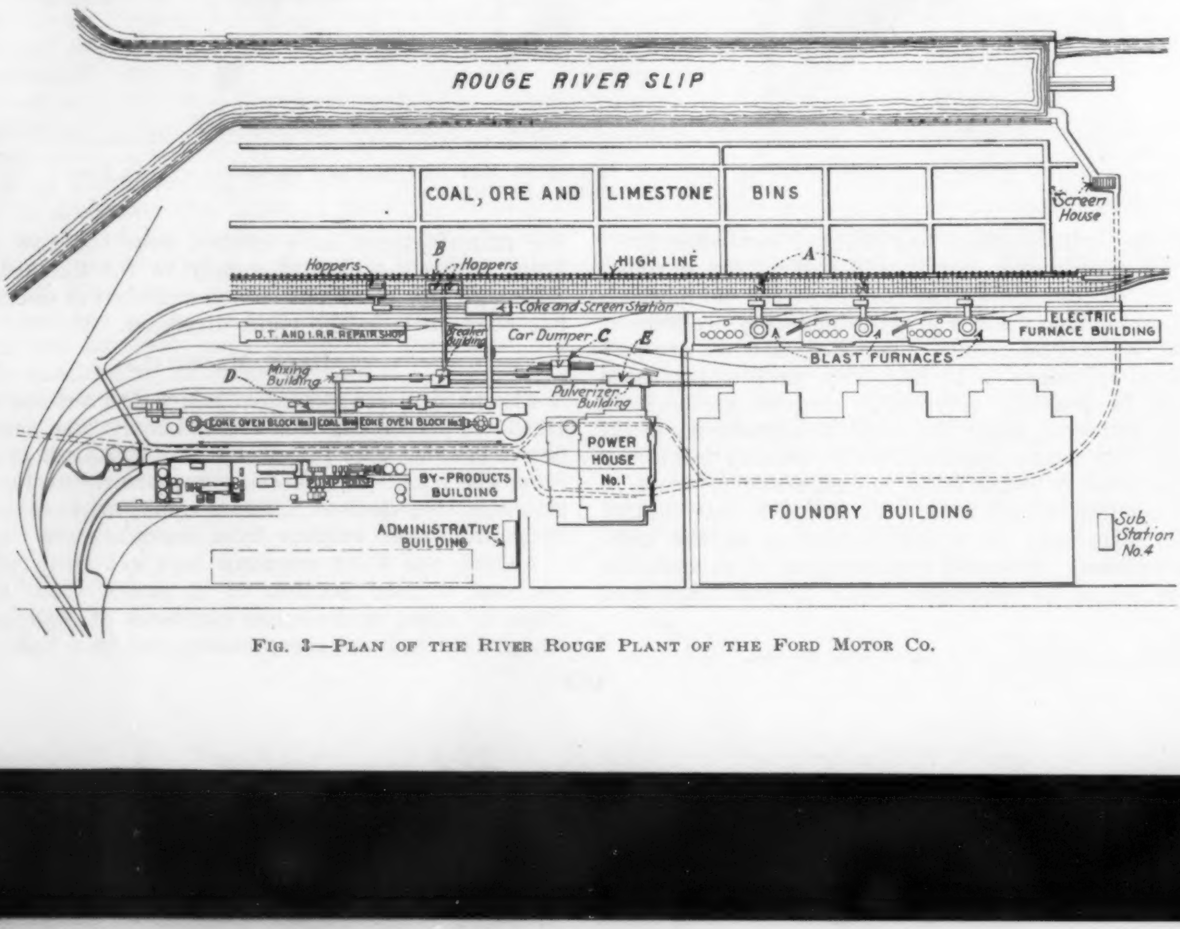

Fig. 3—Plan of the River Rouge Plant of the Ford Motor Co.

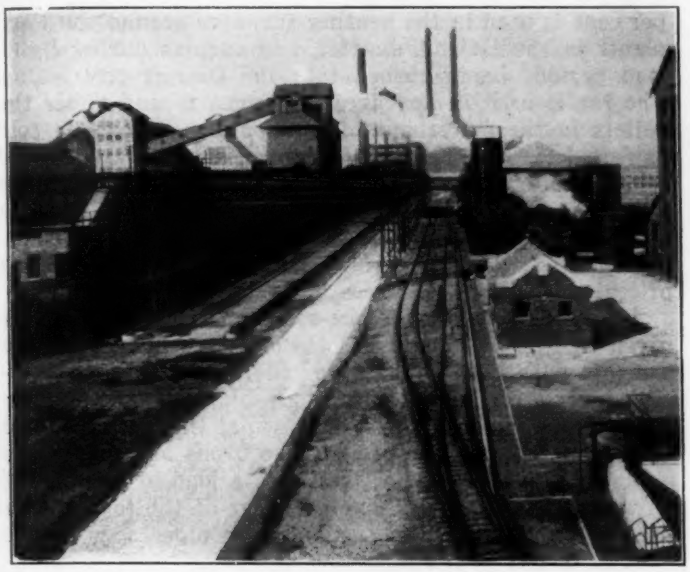

Fig. 5—A General View of the Coke Ovens and the Chemical Plant

inating the profits of dealers, brokers and middlemen, one of our great present-day economic wastes.

Blast Furnace and Coke Ovens

It might be well at this point to describe briefly the fundamental or general plan upon which the layout of this immense plant is based, indicating the results attained by the proper grouping of the units. The basic idea is to connect, with conveyors, each of the important units of the manufacturing plant, thus eliminating rail or truck transportation from one unit to another. To do this the units had to be built as close together as possible.

Fig. 3 shows clearly the relation of the units described in this paper. Iron ore and limestone are transferred to the blast-furnace skip-cars at *A*, where they are weighed and loaded directly into the furnace. Coal is transferred from the storage bins to the hoppers *B* and thence by mechanical conveyor through the breaker and mixer buildings to the coke-oven coal-bin. Coal arriving by rail is unloaded by the car dumper at *C* and conveyed through the same breaker and mixer buildings to the coke-oven coal-bins. The coke is mechanically conveyed from the coke bin *D* to the coke and screen station *E*, there it is graded and distributed by mechanical conveyor to the blast furnace, to the foundry and to storage. The finer coal is pulverized in building *E* and piped direct to the powerhouse.

The powerhouse is located in the center of all of the important units; namely, the coke ovens, blast furnaces and foundry. This is done for the double purpose of placing the boilers close to the sources of by-product heat-energy, and locating the electric generators near the units consuming electric current. The arrangement of

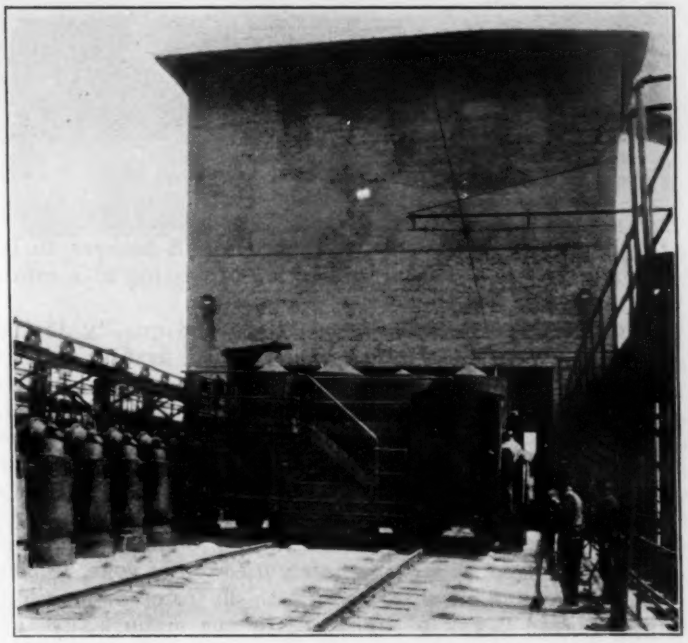

Fig. 6—View Taken on Top of the Coke Ovens Showing the Electric Charging-Car

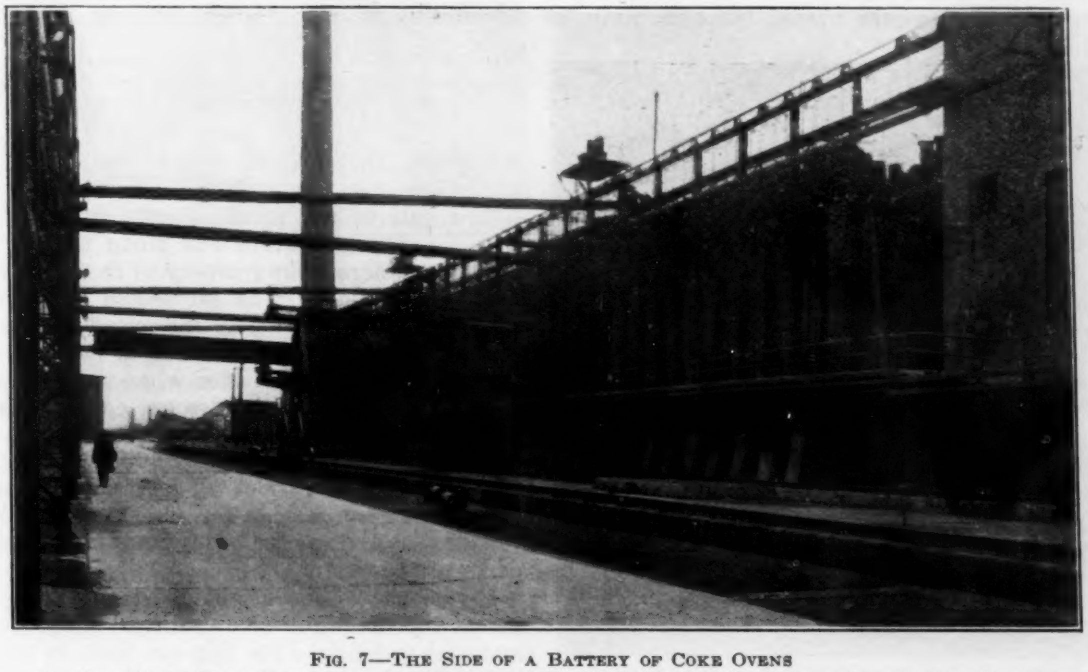

Fig. 7—The Side of a Battery of Coke Ovens
The Gas Mains That Convey the Gas from the Ovens to the By-Products Plant Can Be Seen Running along the Top of the Ovens and across the Roadway. The Car in the Center Carries a Plunger That Is Used To Push the Coke out of the Oven

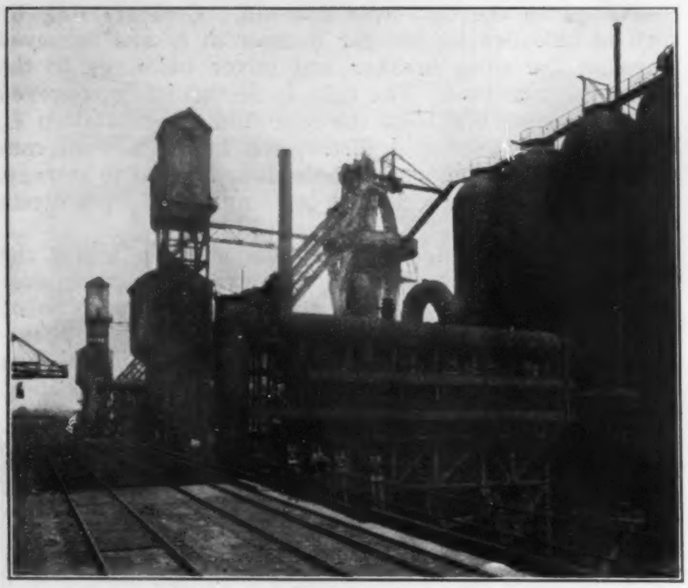

FIG. 8—ONE OF THE BLAST FURNACES THAT PRODUCES 500 TONS OF IRON DAILY

the buildings around the powerhouse will be seen to be justified by the eventual production of casting at a minimum price.

To obtain coke of the proper size and quality at the lowest cost, transportation expense had first to be decreased and the by-products of the coal and blast furnace, which are wasted ordinarily, had to be utilized. Coke is necessary to run the blast furnace and also the foundry cupolas. Since it usually costs the same or slightly more than coal, we buy the coal instead and reap the benefit of the by-products. Fig. 4 shows in diagrammatic form the disposition of the by-products. One ton of coal will produce approximately 0.75 ton of coke, 10,500 cu. ft. of gas, 8.5 gal. of tar, 25 to 30 lb. of ammonium sulphate and 2 gal. of light oil for the manufacture of motor fuel. From this the relative value of 1 ton of coal and 1 ton of coke is readily seen.

Of the gas lowest in by-products and heat value, 44 per cent is burned under the coke ovens; the remaining 56 per cent is used in the heating furnaces around the Ford plants in the Detroit district, any surplus during light-load periods being turned into the Detroit city mains. The tar is used in heat-treating furnaces and under the boilers in the powerhouse. Ammonium sulphate is sold as fertilizer, and the light oil is mixed with gasoline and sold as motor benzol, 10,000 gal. of benzol being produced daily. The economy effected by operating one's own coke ovens is readily seen. At present there are 120 Semet-Solvay coke-ovens in operation; they use about 2000 tons of coal per day.

FIG. 9—BASE OF A BLAST FURNACE SHOWING THE STREAM OF MOLTEN IRON FLOWING TO THE LADLE THAT CONVEYS IT TO THE FOUNDRY

A general view of the coke-ovens and chemical plant is given in Fig. 5. The ovens themselves will be noted at the left with the coal-storage bin in the center, an inclined conveyor rising into its peak from the mixing building. The benzol plant is shown at the right. Fig. 6 is a view taken on top of the coke ovens and shows the electric charging-car that transfers a load of 16 tons of pulverized coal into the four openings at the top of each oven as it requires filling. The riser pipes seen at the left collect the gases from each oven and feed them into the mains.

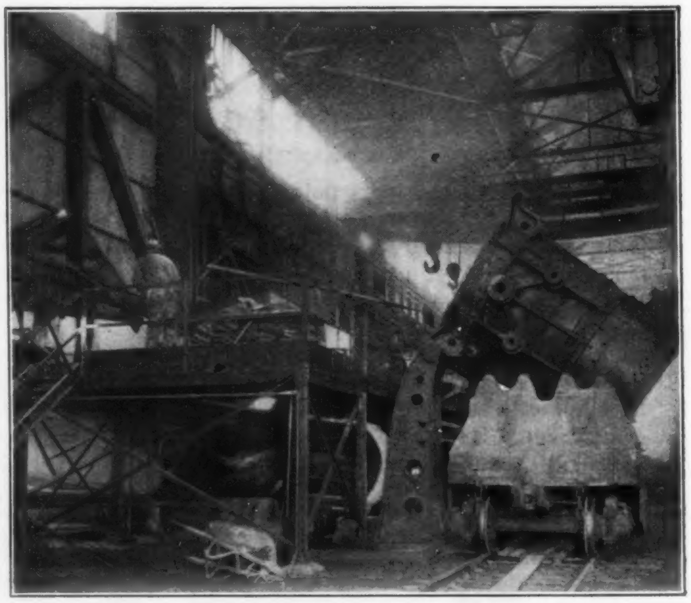

FIG. 10—THE 80-TON LADLE THAT TRANSFERS THE MOLTEN IRON FROM THE BLAST FURNACES TO THE FOUNDRY DISCHARGING ITS CONTENTS INTO A FOUNDRY LADLE

The side of one block of coke-ovens is illustrated in Fig. 7. The gas mains run along the top of the ovens and thence across the roadway to the pump-house and the by-products plant. The car shown in the center of the picture travels parallel to the ovens and carries a large plunger on the inner end of a deep I-beam. This plunger is pushed through each oven when the coking operation is completed, and the incandescent coke is discharged into an electric hopper-car on the opposite side of the oven. The hot coke is quenched and dumped into the coke bins, from which it is carried by mechanical conveyors to the coke and screen station for screening into blast-furnace, foundry and domestic sizes and distribution to other parts of the plant.

Fig. 8 shows one of the blast furnaces, its four air-stoves and the high-line or railroad trestle from which all material is fed into the skip-car that, in turn, travels up the inclined skip-bridge to the charging bell at the top of the furnace. There are two furnaces in the present

equipment, each having a capacity of 500 tons of metal per 24 hr.

We will consider next the benefits of the situation of the blast furnaces. Most people consider a blast furnace an instrument for producing pig iron only. Although its principal product is iron, its by-products are none the less valuable. Note particularly what is produced from a given charge:

Charge	*Products*
1 ton of coke	1 ton of iron
2 tons of ore	½ ton of slag
½ ton of limestone	6 tons of gas
4 tons of air	

The slag, which has been wasted, will be used very soon in the manufacture of cement, much of which will be consumed at the Ford plants for construction purposes. The gas, although of low heat-value, is a very valuable by-product. Nearly half of the blast-furnace gas is required for the four air-stoves which heat in turn the air blown into the blast-furnace. A part is burned to supply the power needed for operating the blowing engines and producing the electric power essential to the working of furnace skips, transfer cars, cranes and the like. Fifty tons of powdered coal and 36,000,000 cu. ft. of gas are burned daily under the boilers in the powerhouse, generating power for departments of the plant other than the blast furnace. This shows clearly the advantage of locating the powerhouse very near the blast furnace.

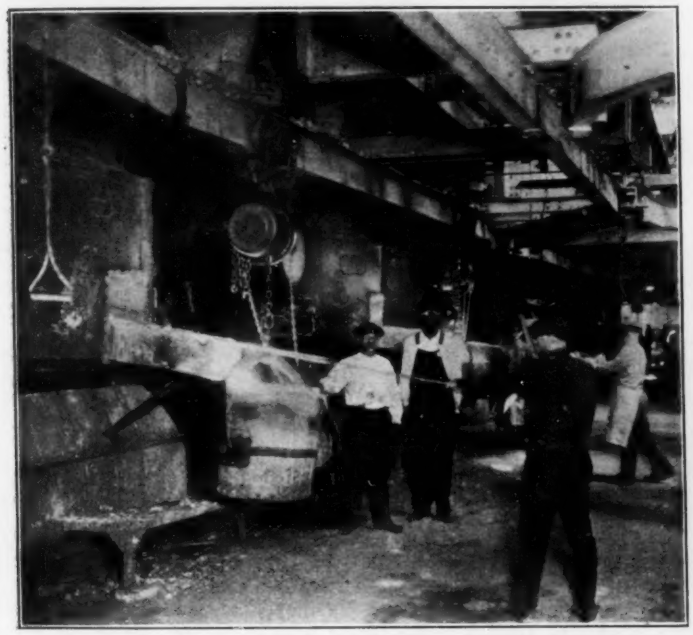

FIG. 11—POURING MOLTEN IRON FROM A CUPOLA INTO A FOUNDRY LADLE THAT IS SUSPENDED FROM AN OVERHEAD MONORAIL SYSTEM

POWERHOUSE AND FOUNDRY

The main powerhouse at the Rouge plant will eventually be the central power-source for all the Ford industries in the Detroit district. Its location at the source of large volumes of combustible by-products guarantees the generation of electric current at the minimum cost. The present equipment consists of four Ladd boilers rated at 2600 hp. each. They are fitted with a combustion system that injects liquid, gaseous or powdered fuel by air pressure. The amount of fuel is controlled electrically to meet the boiler load. Combustion is practically perfect, without ash, cinders or smoke. The customary dirt and disorder of the average boiler-room form a remarkable contrast with the bright tiled floor and orderliness of this plant.

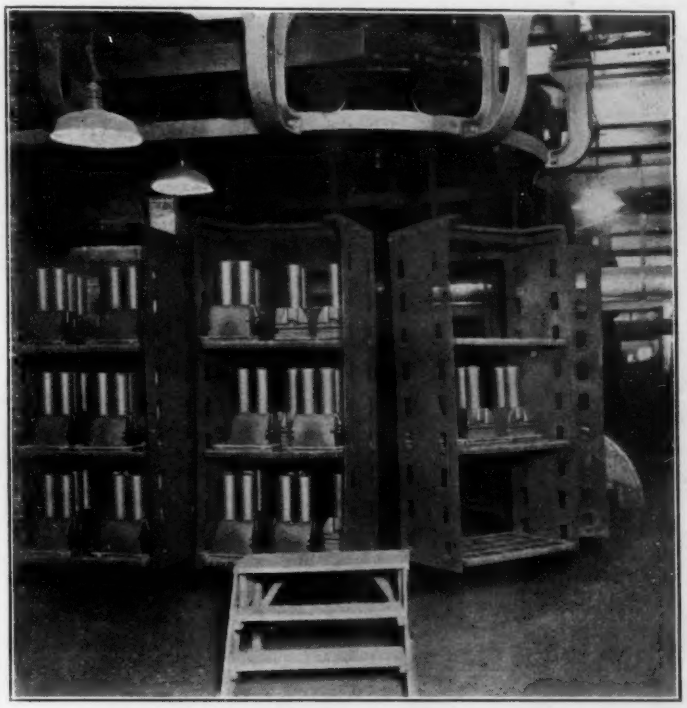

FIG. 12—ALL OF THE MATERIAL USED IN THE CORE ROOM IS HANDLED PROGRESSIVELY BY MECHANICAL CONVEYORS

The electric generating equipment consists of two 12,500-kw. turbo-generator units. This capacity will soon be increased. Three turbo-compressors supply the blast for the blast-furnace line, their combined capacity reaching 45,000 cu. ft. of air per min.

The location of the foundry adjacent to the blast furnace is another basic consideration in the general scheme. Up to this time, pig iron has been taken from the furnace and cast into so-called pigs. These pigs are supplied to foundries and melted in cupolas. It was at this point, in the whole process of iron ore to finished cylinder, that a considerable saving was seen to be possible. One-half

FIG. 13—ONE OF THE CONVEYORS EMPLOYED IN THE CORE ROOM

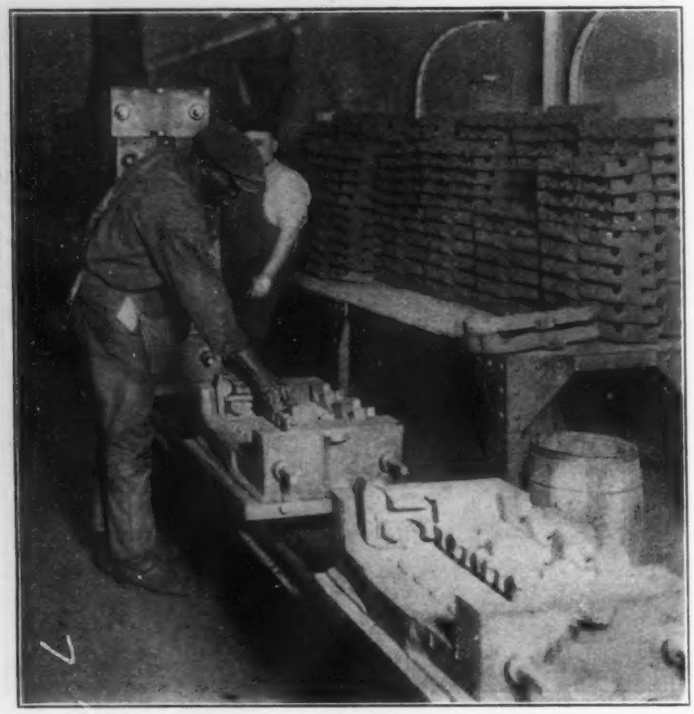

Fig. 14—Setting the Cores in the Drag Portion of a Mold as It Passes Along on a Mechanical Conveyor To Receive the Cope Portion

of the heat generated in the blast furnace is retained in the molten iron itself. Mr. Ford believed this heat should be conserved. In a foundry where approximately 1400 tons of iron is melted per day, this item of heat loss is a considerable one.

Through misinformation or misunderstanding, many writers have stated repeatedly that the blast-furnace iron is cast directly into molds without any additions or special treatment. This is possible; but it is not practicable because the iron produced by the modern blast-furnace contains too much carbon and its analysis is too variable for direct casting. To overcome this variation and to lower the carbon-content, a process has been adopted in the Ford foundry. This process enables us to use the foundry scrap and so-called back-stock that amounts to approximately 50 per cent of the iron poured into the molds. About 30 per cent of the iron poured into the Ford cylinder-mold is blast-furnace iron. The remainder is tapped from the cupolas and maintained at an analysis suitable for bringing the iron in the casting to a composition that agrees with our requirements. The percentage of manganese, sulphur and phosphorus is practically the same in both cupola and blast-furnace iron, silicon being the only element manipulated to make either soft or hard iron according to requirements. If an iron of 2-per cent silicon is required, for example, and the blast furnace is producing iron of 4-per cent silicon-content, the cupola would be run to produce 1-per cent silicon iron to give the desired chemical analysis.

Fig. 15—Pouring the Molds

Fig. 16—After the Molds Have Been Poured They Travel to the End of the Outside Conveyor Where They Are Shifted Mechanically to the Center Conveyor That Carries Them to the Shake-Out Room

Fig. 9 shows the base of a blast furnace from which the metal is being drawn. The molten iron flows through a channel directly into an 80-ton ladle outside the building. The blast-furnace iron is conveyed by rail directly to the foundry in this ladle. Here it is tilted to the position shown in Fig. 10 by a gantry crane and discharges its contents into a cylindrical container mounted on an electrically propelled car. This car takes the iron to a point between two batteries of cupolas of four each and turns its contents into the foundry ladles hung from a monorail running over the cupola spouts and at right angles to them. The foundry ladles, after receiving a weighed amount of furnace iron, are taken to the cupolas to get their portion of cupola iron and then taken to the molds to be poured. Fig. 11 shows the foundry cupolas, ladle and monorail carriers. Twenty-four cupolas are arranged in batteries of eight each and these, with three stations for furnace iron, take care of the entire production.

Making the Cylinder Block

The foregoing is intended to show the magnitude and efficiency of the system needed to bring the iron to the molds at a low cost. Having provided good iron at a

minimum cost, additional economies must be effected in the molding end. Heretofore, castings have been made either in molds on the floor or on benches, from which they were transferred to the floor to be poured-off. This system was crude and wasteful in addition to being laborious. The molder was compelled to carry flasks from a pile or from the yard, fit his own cores and pour the iron. In the Ford foundry every workman has all the materials he works with brought directly to him.

The system or group of conveyors, molding machines and the like comprising one unit occupies a space only 50 x 300 ft. in area. Corerooms are situated between each two systems on the same floor-level. The shake-out, where the casting is removed from the mold, is at the rear of each system. Back of this is a large cleaning-room receiving the castings from the entire system.

The cores are made from new or green sand bonded with linseed oil or a mixture containing linseed oil, or with burnt or used sand bonded with compounds made principally from pitch. The green-sand cores are used where they are surrounded by metal, and the burnt-sand cores when they are only partially surrounded. All material in the corerooms is handled progressively by conveyors as shown in Figs. 12 and 13. The core-drying oven is placed near the center of the coreroom. Cores are made at one end of the room, dried in a continuous

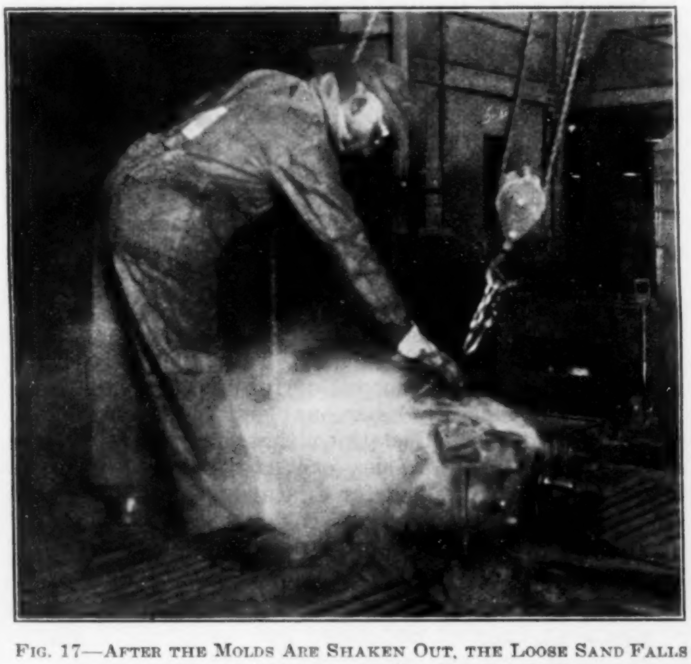

FIG. 17—AFTER THE MOLDS ARE SHAKEN OUT, THE LOOSE SAND FALLS THROUGH A GRATING TO A SUNKEN CONVEYOR

oven and carried by conveyor from the oven to the storage space at the opposite end of the room. The cores are taken from storage to the molding machines and used as required.

The cylinder is molded on the two outer chains of a system of three parallel conveyors. The two outside conveyors travel in the direction of the cupolas, while the center one moves in the opposite direction to the cleaning-room. Molding machines are placed on both sides of this system. The drag or bottom portion of the mold is rammed by hand near the starting point of the outer conveyor. Immediately after the drag has been rammed-up it is placed on the outside conveyor and, while in motion toward the cupola end, the cores are set. Fig. 14 illustrates this stage of the molding operation. Farther on the cope or top half of the mold is rammed-up and

FIG. 18—APRON CONVEYOR THAT DELIVERS TEMPERED SAND TO THE HOPPERS DIRECTLY ABOVE THE MOLDING MACHINES

placed on the drag. After this the copes and drags are clamped together and the runner or basin that receives the molten metal is made preparatory to pouring.

Pouring the molds takes place at the cupola ends of the outside conveyors as illustrated in Figs. 15 and 16. After being poured, the molds travel to the end of the outside conveyor and are shifted mechanically on a series of rollers to the center conveyor and started back toward the shake-out room. The iron solidifies and the castings become partly cool on their passage through the ventilated tunnel over the center conveyor. This removes a large amount of gas and smoke from the foundry. After

FIG. 19—HOPPERS SUPPLYING SAND THAT STILL RETAINS SOME HEAT FROM THE PREVIOUS CASTING TO THE MOLDING MACHINES

the shake-out, the castings are transferred to a conveyor leading to a mezzanine floor and the loose sand drops to a sunken conveyor through a grating, as shown in Fig. 17. Enough new sand is added to the portion passing through this grating to replace the sand still adhering to the casting. The replenished sand is then automatically conveyed through a riddle or beater to break up the lumps and also through a mixer. The whole process is mechanical except the tempering, which is looked after by a man whose duty it is to add the required amount of water to dampen the sand. After this preparation, the sand is elevated by an apron conveyor shown in Fig. 18, which passes over the supply hoppers directly over the molding machines. Sand is drawn from these hoppers, which are shown in Fig. 19, through hand-controlled gates as each molder requires it. The sand has now completed a cycle and is ready for another mold. It is still warm from the previous casting.

The cylinder castings lie on trays until cold enough to handle and are then taken to the so-called knock-out where the bulk of the core sand is removed. This is accomplished at present by using pneumatic chisels, the cylinders resting on a grating similar to that on which the molds are shaken out. In this case, however, the burnt sand, when recovered, is used by the coreroom after proper tempering and preparation.

Cold cylinders, free from the bulk of sand in which they were cast, are then loaded on a conveyor which transfers them from the mezzanine to the ground floor where the tumbling-mills are located. A group of these mills is provided for each system. This particular conveyor also passes the cylinders between the tumblers that are grouped in two parallel rows. The cylinders are transferred by hand into the tumblers. The tumbling requires from 2 to 3 hr. The castings are removed from the tumblers by rope-hoists, returned to the same conveyor and transported to roller conveyors where the core wires are removed. From the roller conveyors, they are started on the last operations; these are performed on a slat conveyor. A crew of men on either side of this conveyor chip, grind and otherwise clean and prepare the cylinder-blocks for inspection. The rejected cylinders continue on the slat conveyor to a point farther on, where they are checked to determine the cause of rejection, removed to a truck and taken to the cupola-charging platform. The accepted castings are transferred to another slat-conveyor that runs at right angles to the cleaning conveyor; thence they pass into the machine-shop. Machining commences without delay, since the machine-shop is in the building that houses the foundry.

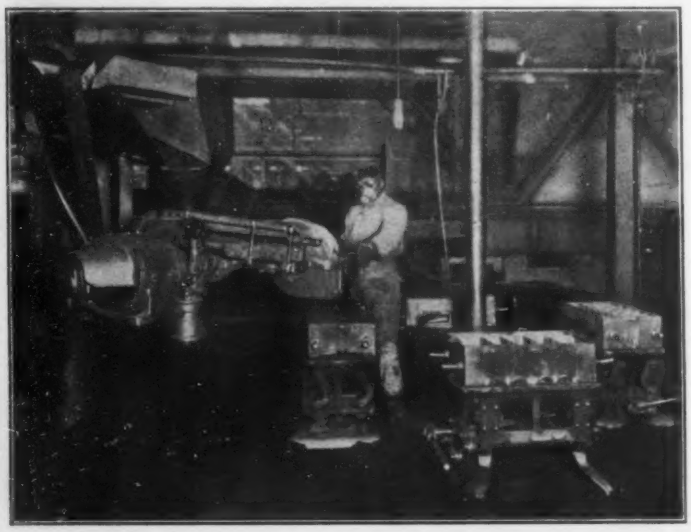

FIG. 20—AN EXPERIMENTAL MOLDING MACHINE THAT IS DESIGNED TO ELIMINATE HAND RAMMING IN WHICH THE SAND IS PACKED BY BEING THROWN INTO THE MOLD AT A HIGH VELOCITY FROM THE PERIPHERY OF A REVOLVING WHEEL

The Ford cylinder, although simple as compared to other cylinders, is the most complex and difficult casting in the car. In its molding many troubles come up, which are ascribable mostly to its high production. Patterns wear rapidly due to abrasion by the sand and rough usage by machine-molders. They are being repaired continuously. The molding-machines also require attention nearly every week. The big problem of cylinder production lies in the constituents and usage of the sand and the iron. In a machine-shop most operations and materials are visible. The same thing is true of the patterns, machines and conveyors. A good mechanic who is always on the job is all that is required, but in the case of both the iron and the sand slight variations are hardly noticeable. Nature is not dependable when it comes to uniformity. The sand used in both molding and coremaking is ever-changing. What is right one day as regards mixtures may be altogether wrong the day following. Only certain grades of sand can be utilized successfully on a job where production is high and only common labor is employed. Sand varies with every different source of supply and even in the same pit. Shipments of sand are watched very closely. A certain amount of bond and a grain size have been determined upon and are adhered to as closely as possible. The sand must also be rammed properly. A mold rammed too hard or not enough will produce an inferior casting. Cores must be maintained at a certain composition; the voids between the grains must be sufficient to allow free passage of gases. The cores have to be strong enough to withstand rough handling and must not be easily destructible by the high temperatures of molten or very hot iron. No set rule is applied to our sand problems; the make-up of a core is modified to meet the difficulties as they arise.

Iron for the cylinder also requires constant watchfulness. The composition of scrap-iron is never dependable, due to a certain amount of foreign scrap that gets into our back-stock. The amount and condition of steel in the charge also affect the ultimate product, and the composition of coke varies over a considerable range. When melting back-stock for mixture with blast-furnace iron, we use about 1 part of coke to 6 parts of metal. The analysis of iron for the cylinders that is found to keep porosity at a minimum and at the same time permit easy machinability is as follows:

Silicon, per cent	2.20
Phosphorus, per cent	0.35
Sulphur, per cent	0.08
Carbon, per cent	3.30
Manganese	0.80

The process of manufacture as outlined serves us today, but it is continually being developed to a finer degree in accord with the policy of the company. The difficulties due to the human element have been reduced to a minimum and, although there are still some severe working conditions on the cylinder line, they are being eliminated one at a time. The hand-ramming probably will be replaced by a machine operation, upon which we are now experimenting; the cooling of the cylinder will take place while the latter is in motion, the present cooling-trays being eliminated. The experimental molding-machine is shown in Fig. 20. Sand is thrown into the mold at a considerable velocity from the periphery of a revolving wheel, and it seems to pack satisfactorily.

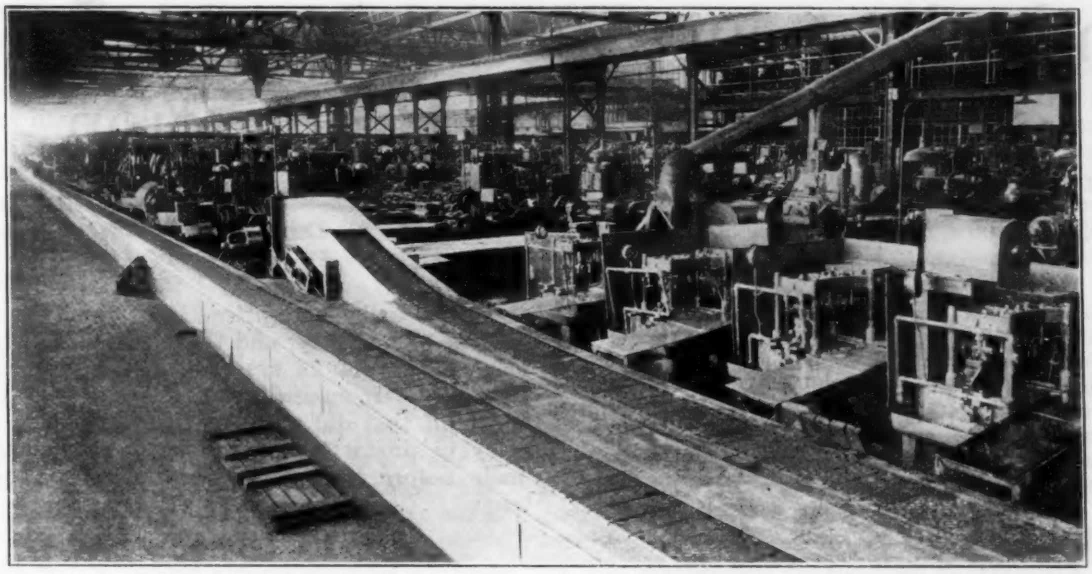

FIG. 21—GENERAL VIEW OF THE CYLINDER MACHINE SHOP

MACHINING THE CYLINDER

The cylinder block, as it comes from the foundry, is inspected for any foundry defects before being removed from the conveyor. The block is not allowed to touch the floor at any time in the actual operation, but moved from one machine to another by conveyors that are as nearly of the same height as the machines as possible. Two of these conveyors are shown in Fig. 21.

The first step in the machining operation is to locate four spots on the upper side of the block. This is done in two specially designed machines. The block then goes to a standard milling-machine to have the crankcase flange milled. After this the six main bearing boltholes, which serve as locating points throughout the entire operation of machining the cylinder block, are drilled and reamed. The top or head side of the block and the water-connection and the manifold side are next milled in one operation. The block is then placed on a four-spindle drilling-machine and a rough-cut taken out of the cylinder bore so that the casting can be tested under a water-pressure of 65 lb. to eliminate any castings that may be porous and will not stand pressure.

Several smaller milling and drilling operations come next. After this the block goes to multiple-spindle drilling-machines to have the port, valve-stem and push-rod holes bored. All of these machines are equipped with suitable fixtures so that accurately finished work can be turned out rapidly. The radius for the transmission cover is then turned on a standard lathe having special equipment to load and turn two blocks at once. Boring of the camshaft holes is next in order and this is done on a special machine that works from both ends of the block. The block is rebored and also reamed on a four-spindle machine that is similar to the one used to take the first rough-cut out of the bore, some changes in the feed and the speed of the tools of course being made on account of the difference in the nature of the work. The block is then ready for the three-way machine that drills five holes in the top, eight in the manifold side and two in the water-connection side. The block is then put in a four-way machine that drills 15 holes in the top, 4 in the front, 5 in the rear and 17 in the crankcase flange, the entire operation being completed in about 50 sec.

The next major operation is casting the babbitt in the main and crankshaft bearing and milling off the gates in a conveyor machine of special design. The babbitt is then planed to insure the proper fit in the cylinder casting and the correct density of the metal. The next step is the very important one of rolling or glazing the bore, which is done with a four-spindle standard machine driven by a reversible motor. The rolls, which are of special design, are ground very accurately and hardened very uniformly. The block is then placed in a specially designed two-way tapping-machine where 10 holes on one side and 2 on the other are threaded simultaneously. The next and last stage in the machining is the tapping of 15 holes in the top of the block, 4 holes in the transmission end and 3 holes in the front end at the same time by a three-way tapping-machine. From the completely machined blocks we receive approximately 70 tons of chips per day, which are returned to the foundry and immediately remelted to provide the cupola iron needed to make more castings.

After being completely machined the block goes through a specially constructed washing-machine and comes out on a conveyor to be inspected and given the final water-test. If it passes the inspection and test satisfactorily the cylinder block is stamped "ok" and travels along on a conveyor to the loading dock from whence it is shipped to the assembly plant.

MOLDING SAND INVESTIGATION

THE Bureau of Standards is conducting a series of tests to discover a sand with 100-per cent permeability. The advantage of finding a perfectly permeable sand or one that approximates perfect permeability is obvious. Having a standard sand with a known permeability, the suitability of every molding sand could be expressed as a percentage of the sand that was found to be 100 per cent permeable. To accomplish this result, several sands have been investigated. One commercial grade of sand, which is a very pure silica sand of a fairly uniform degree of fineness, has been found on a number of tests, both dry and with as high as 4 per cent of moisture, to be 100 per cent permeable. Further tests are being made to determine its colloidal matter or any other substances that might affect its permeability.

Standard versus Special Machine-Tools for Automotive Production

By R. K. Mitchell[1]

Detroit Production Meeting Paper

THE too prevalent tendency toward making large expenditures for special equipment when standard machine-tool equipment might well serve the purpose is deplored by the author, and a plea is made for the reduction of the altogether too large investment often carried under fixtures and permanent tools. Ill-considered plans may have as their objective only the design of some special fixture, but frequently result in a fixture or machine-tool that requires special driving and feed-mechanisms.

Some of the disadvantages that attend the use of special machines are stated and commented upon, and the benefits of using standard equipment whenever possible are set forth. Reference is made to possibilities of special jig-and-fixture design that would meet the needs of manufacturers of standard parts.

THIS paper is not an attempt to dictate a set rule or policy for the tool engineer or tool designer to follow in every problem that presents itself. Rather, it is a general adverse criticism of the present prevailing policy of making large expenditures for special equipment when standard equipment might well serve the purpose, and also a plea for the reduction of the altogether too large investment carried under fixtures and permanent tools.

There was a time when the automotive manufacturer found it necessary to build special machines for performing certain operations and making special parts. When an operation or a part of this description was required, the policy was to design special fixtures and machine-tools to meet the special conditions. But often when the original intention is only to design a special fixture, the ultimate result is a fixture or machine tool that requires special driving and feed mechanisms. Then comes the question of whether to design special drives and feeds for some machine that is already in the plant; and this is the critical point in the argument between special tools and standard equipment. In many instances the only machine tool that will accommodate the special heads is one designed and built purposely to meet this one particular difficulty; so, we arrive, perhaps unintentionally, at the stage we have so much desired to avoid, which is the design and fabrication of special machine-tools.

In the ordinary routine followed when building special machine-tools, we are confronted with numerous obstacles. The first is the fact that the average draftsman found in the general run of tool-designing departments has had neither the engineering nor the production experience essential to the proper designing of special machine-tools, and his lack of knowledge as to proper stresses, correct bearings, loads and the details to be employed, together with a lack of foresight in considering the interchangeability of parts, ease of replacement and the use, so far as possible, of standard parts, is reflected in the enormous first cost of the majority of special machine-tools that are built under private supervision. The actual construction usually is performed in the toolroom by high-priced labor, working an excessive amount of overtime, and the machine, finally completed, has yet to meet its first test. It will be acknowledged that very few special machines have ever been devised and built that did not demand much undue expense and delay in production, not to mention the many changes made before they began to function as originally intended.

Special Machinery

The governing motive behind the design of special machinery is usually economy in production, and this is very commendable; but lack of experience, errors in design and construction and the failure of a machine to work as intended do not pay dividends. For example, a special machine-tool for turning both sides of the flange and the face of a flywheel at one operation was designed and constructed recently at an expense of from $18,000 to $20,000. Three days after the machines were installed, they were abandoned; but, fortunately for the manufacturer, the old set-up was still available. This was not because the old set-up was more efficient; but because, although there was every opportunity to develop a machine that would give greater production, lack of foresight and poor design ruined the whole project. The worst blunder was that no provision had been made or could be made for the escape of chips. Chips from the upper cutters worked down and packed against the bottom face, impeding the two lower cutters and necessitating the removal of the chips with a chisel about every 10 min. The final outcome of this case was that the manufacturer had to go out in the market and buy standard machine-tools. If the outlay wasted in the design and construction of the special equipment had been applied to the purchase of standard equipment, it would have more than covered the standard machine-tools that were afterward purchased. The sum of the whole incident was that from $35,000 to $40,000 was expended, where $15,000 would have served the purpose. This is rather costly experimental work for the manufacturer. The money spent and wasted on this job alone should be a sufficient argument against the too prevalent weakness for designing special machinery on the least provocation.

A special machine-tool in production requires the services of a skilled or special operator, at least until those interested become familiar with its care and operation. If the operator should be absent for any reason, loss of time and production must result before another man can be broken-in.

Repair parts for special machine-tools are costly items. It develops not infrequently that patterns are broken, mislaid or left at the foundry and, when the casting is finally secured, it means day-and-night work in the toolroom with additional expense and delay. Perhaps all of the foregoing will be accepted as constituting problems that will arise in any trade or line.

The most forceful argument against special machine-

[1] Production department, Maxwell Motor Co., Inc., Detroit.

tools at present is the unstable design and development of automotive parts. When a designer produces a special machine-tool to accommodate a certain part, he has no guarantee as to the life of that part. I venture to say that the average life of the majority of automotive parts without change in design is less than 6 months. Any change in the design of the part either obsoletes a special machine-tool or demands such expensive changes in its construction that the machine usually finds its way to the obsolete or salvage department long before its useful life has scarcely begun.

Standard Equipment

Let us consider now some of the advantages of using standard equipment and machine-tools. To-day, machine-tool builders have stocked the market with a large variety of simplified, standard machinery that can be adapted to special operations and parts with slight extra expense. In the first place, the standard machine-tool is very much cheaper than a special machine. It is built on a quantity-production basis, and designing and engineering charges are distributed over a greater number of units. The standard machine-tool is available for prompt delivery. It will have had a thorough trial in practical work before being placed on the market and passed out of the experimental stage. Reputable manufacturers of standard machinery build their machine-tools so that the parts are interchangeable and, in case of service requirements, are prepared to furnish any part promptly from stock. Consider for a moment the money that is tied up in special machinery patterns, extra castings and the like. With a standard machine-tool, in production in any large shop, if an operator is called from his machine, other men just as familiar with the operation of it are always available and capable of continuing production without loss of time.

Sometimes it is advisable to have special features on machine tools, such as a special number of spindles, possibly set at different angles, on a milling-machine. It has been proved that a standard make of milling-machine can be equipped with a suitable special head to take care of special work. If the special part made by the special head is ever changed or made obsolete, the manufacturer need not scrap the entire machine, but only the special tooling. In the case of a special machine-tool for this special work, the entire machine would become obsolete in such an instance. Also, the standard machine-tool with the special tooling can be secured in much less time and with far less expense than the special machine-tool. In the case of the standard machine-tool, if the special part only is scrapped, the machine itself still is adaptable to any other operation of a similar nature.

The foregoing example is cited simply to show what is possible with standard equipment on milling machines, but it is true also with lathes, grinding-machines and many other standard machine-tools. All I have attempted to deal with is the too-ready penchant for designing and building special machine-tools where the exercise of a little ingenuity and manipulation will produce a set-up that will serve the purpose just as satisfactorily, without the excessive outlay usually associated with the fabrication of special machine-tools.

Special Fixture Design

I believe there is ample room for improvement in the design of special fixtures. Too little attention is paid to the needs of manufacturers of standard parts whose product, if properly investigated, will be found to contain unlimited possibilities for incorporation in the design of special jigs and fixtures. In a recent issue of a popular weekly periodical there was a full-page spread advertising the merits and possibilities of standard bushings. This advertisement alone probably meant an expenditure of from $8,000 to $10,000 for that manufacturer. With dozens of companies in like manner placing their engineering staffs and experience in their particular line at our disposal, still we do not pay enough attention to their claims and the merits of their products to consider them when designing our own pet tools and equipment. So far as possible, when designing fixtures and tools, we should take advantage of all that the trade offers and attempt to simplify our creations. Frequent use of the three fundamentals of jig and fixture work, the clamp, the V-block and the angle-plate, is to be recommended.

As a recent instance, a large drum-type fixture was designed, built and installed on a machine. The cost was about $2,500, including special drive-gears and the like that were constantly breaking, delaying production and running up a continuous repair bill on this job. The annoyance and continuous expense demanded immediate action and the whole fixture was replaced with two small angle-plate fixtures on which V-blocks to oppose each other were fastened. One side was loaded while the part on the other side of the fixture was being milled. These two fixtures cost about $70 and actually increased the rate of production beyond that of the more elaborate and expensive fixture. This is only one of various similar instances that occur every day. I believe that the tool designer is so prone to become interested and intent on the design and construction of the fixture that he temporarily loses sight of the fact that the fixture or tool is not the ultimate issue, but only the means to an end.

MOTOR-VEHICLE KILLINGS AND THE ENGINEER

In the year 1921, the Bureau of the Census announces, 10,168 deaths from accidents caused by four-wheel motor vehicles occurred within the registration area of the United States, which contains about 82 per cent of the population. This is a death rate of 11.5 per 100,000, an increase of 28 per cent over 1917. Further than that, the increase in rate is itself increasing from year to year, and the rate in the 65 largest cities averages about 15 per 100,000. These are alarming statistics. Couple with them the statement just made by Chief Magistrate McAdoo of New York City, that before long all of Manhattan Island below 14th Street will have to be one-way streets barred to passenger vehicles and that there are 2000 unprotected crossings in the city where policemen are needed, and the seriousness of the motor-traffic problem will be realized. Part of the trouble is due to the laxity of the driver license requirements, part to the carelessness of drivers and their assumption of the right-of-way over the pedestrian at crossings, but mostly it is the inevitable result of an increase of motor use far beyond the capacity of a city street system laid out for slow moving traffic in small volume. This motor use will not decrease nor even remain stable. Driver and traffic regulations can only remove a part of the difficulty. The obvious solution lies only in a radical revision of our conception of what a city street is for, and this reduces to a problem for the engineer. Motor-vehicle boulevards, second-story streets and under or over crossings for pedestrians all are probabilities of the near future in our congested centers and engineers responsible for our city developments must take account of such things as actualities and not as dreams.—*Engineering News-Record.*

The Hot-Spot Method of Heavy-Fuel Preparation

By F. C. Mock[1] and M. E. Chandler[2]

Semi-Annual Meeting Paper *Illustrated with* Drawings

SINCE a number of verbal additions were made at the meeting to the preprinted text of the paper, particularly in the way of making clear first how far actual working conditions followed out the theoretical analyses, these are printed herewith to avoid the possibility of making incorrect assumptions from the previously printed text. For the convenience of the members a brief abstract of the paper as it was printed in the July issue of The Journal[3] is presented herewith.

ABSTRACT

THE development of intake-manifolds in the past has been confined mainly to modifications of constructional details. Believing that the increased use of automotive equipment will lead to a demand for fuel that will result in the higher cost and lower quality of the fuel, and being convinced that the sole requirement of satisfactory operation with kerosene and mixtures of the heavier oils with alcohol and benzol is the proper preparation of the fuel in the manifold, the authors have investigated the various methods of heat application in the endeavor to produce the minimum temperature necessary for a dry mixture.

Finding that this minimum temperature varied with the method of application of the heat, an analysis was made of the available methods on a functional rather than a structural basis. Three of these are discussed: (*a*) When the heat from the walls of the manifold is applied through the medium of the air; (*b*) when it is applied to the fuel alone, or partly to the fuel and partly to the air; and (*c*) when a spray of atomized fuel and air is directed against a heated surface. A device was constructed by which the three main variables, the exhaust temperature, the exhaust flow and the area of the heating surface, might be regulated and the three remaining variables, the quantity of air, the quantity of fuel supplied and the quantity of fuel vaporized, might be controlled.

Taking into account the wide range of temperatures that the air charge and fuel supply undergo before entering the intake-manifold system, a quantitative computation of heat transfer was made and the conclusions were drawn that only by a combination of centrifugal force, surface tension and the force of gravity could the unvaporized drops be separated from the fuel charge and that the conditions of combustion are governed by the rate of fuel feed from the manifold to the cylinder and not from the carbureter to the manifold.

THE DISCUSSION

F. C. Mock:—Supplementary to the paper, reference is made to an experiment with a hot-spot type of fuel heater in which the area of heating surface, mixture proportion and exhaust temperatures could be varied while observations of the condition of the fuel and temperatures in various parts of the system were made. This device is shown in Fig. 8 of the paper. It was mounted in the center of the exhaust manifold of a Continental Model 7-R $3\frac{1}{4}$ x $4\frac{1}{2}$-in. six-cylinder engine, which was operated for several weeks with this device, on motor gasoline, high-test or aviation gasoline, kerosene and grain alcohol. It should be stated that this form of heater, having a horizontal heating surface, was not selected as being a desirable form for regular use in automotive service, but was chosen because of the convenience with which observations could be made.

Nature of Action at Hot-Spot

Our observations seemed consistently to show that whatever part of the fuel remains in contact with the hot-spot undergoes a sort of selective distillation, the light elements boiling off quickly and the heavier elements more slowly, being very much the same action as that in the distillation flash of Prof. R. E. Wilson's method for determining equilibrium solutions. Provided the temperature of the metal heating surface is above its boiling-point, each element of the fuel seems after boiling to depart from the pool of fuel on the heating surface as vapor at its own boiling-point. Very little heat is apparently communicated from the metal heating-surface and the liquid on the heating-surface to the airstream, and the final mixture-temperature is approximately such that its heat-content is the sum of that of the air part of the charge at its entering temperature and that of the fuel vapor at its average boiling-point. In other words, the heat balance and final mixture-temperatures with an exhaust hot-spot are substantially those obtained with the system shown in Fig. 4 of the paper. This combination then results in a fog mixture, the temperature of which depends upon the boiling-point of the fuel, its specific heat, the mixture proportion and the temperature of the entering air.

Fig. 10 shows the mixture temperatures that should result from the combination of gasoline and kerosene vapor with varying temperatures of the entering air. It should be borne in mind that such low mixture-temperatures as these can scarcely be obtained under a motor-car hood because of preheating of the air, and later heating of the mixture, from sources external to the hot-spot. With the greatest care that can be taken, the mixture will enter the valve ports from 15 to 25 deg. fahr. hotter than indicated by the curves.

The temperature values given for motor gasoline and kerosene are those computed from the observations of Prof. R. E. Wilson and Daniel P. Barnard, 4th, described in their paper on Condensation Temperatures of Gasoline and Kerosene-Air Mixtures,[4] which check very closely our own observations. For convenient reference, curves of the heat-content of gasoline and kerosene at different temperatures and at pressures corresponding to those of

[1] M.S.A.E.—Research engineer, Stromberg Motor Devices Co., Chicago.
[2] M.S.A.E.—Engineer of carbureter design and development, Stromberg Motor Devices Co., Chicago.
[3] See The Journal, July, 1922, p. 27.
[4] See The Journal, November, 1921, p. 313.

the vapor in the mixture at full throttle, are given in Fig. 11 in terms of British thermal units and degrees fahrenheit. These also were obtained from the work of Professor Wilson and Mr. Barnard and can be used to compute the rise in temperature necessary with different mixture-proportions, initial air temperatures and the like.

With the ordinary hot-spot, the fuel remains on the surface only at low air velocities in the manifold, and in customary use a considerable portion of the fuel goes by into the engine without having gone through the process of evaporation and condensation, so that the conditions described in the foregoing, and in the paragraphs following, are only partially carried out. Such fuel as does not boil at the hot-spot is carried farther along into the intake manifold where further evaporation takes place from its surface at a relatively slow rate.

When the temperature of the metal heating-surface was 200 deg. fahr. or more above the boiling-point of the fuel, there was a pronounced "spheroidal condition" and at times the drops of fuel would bounce around in the chamber like popping corn. Under this condition, a number of drops were caught up by the airdraft and swept out of the heating chamber into the intake-manifold without being evaporated. In our test, however, we found this only occasionally and as a temporary phenomenon, as it was only at the highest power outputs of the engine that the heating surface rose sufficiently beyond the boiling temperature for this condition to occur.

Final Limitations of the Hot-Spot Method

With kerosene and with alcohol, the temperature of the metal surface sometimes fell below the boiling-point of the fuel. Under such conditions the evaporation took place by surface evaporation rather than by the combined surface and internal evaporation of boiling, and consequently a considerably larger surface area was necessary at this time. It should be borne in mind that, during boiling, the limitation of heat transfer was probably the ability of the ribs to collect heat from the exhaust, as the rate of transmission from the metal surface to the liquid was sufficiently rapid to take away the heat as fast as it was collected from the exhaust. When the evaporation is only from the surface, however, the extent of surface presented is the main limitation and it becomes necessary to spread the fuel out in a very wide film or to recirculate and respray it on the hot-spot. Whether this surface evaporation can be obtained is, in our estimation, the consideration that will determine how low we can go in the scale of fuel elements, using the hot-spot method of preparation. It seems very likely that we will not be able to use successfully, in general service, fuels the boiling-point of which lies above 500 to 550 deg. fahr., so long as a low "idle" is desired; because, even allowing for the effect of the reduced intake pressure in lowering the boiling-point, the exhaust temperatures will not be adequate.

The heat for evaporation of fuel is obtained from the exhaust through the intermediation of the metal wall between, and the wall temperature is, therefore, lower than that of the exhaust but higher than that of the liquid film. The temperature of the heating surface, like the exhaust temperature, varies with the speed; but the percentage of variation is less. We found that the temperature drop of the heating surface under change of quantity or condition of mixture fed was a very good measure of the heat being taken up by the mixture. Any change of boiling-point, specific heat or latent heat of evaporation in the fuel is strikingly shown in the temperature of the heating surface. For instance, with the exhaust temperature at 1000 deg. fahr., the metal-wall temperature at one point was with motor gasoline 595 deg., with kerosene 535 deg., and with alcohol 175 deg. fahr. This emphasizes what has been implied previously, that with alcohol and kerosene it is very important that an adequate amount of surface be presented to collect heat from the exhaust.

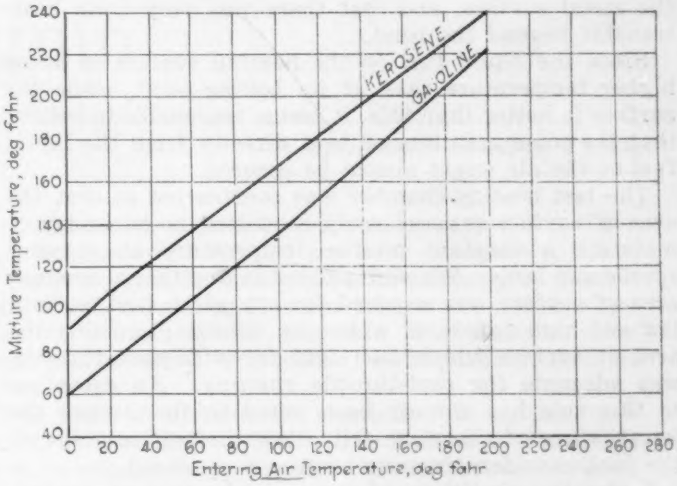

Fig. 10—Temperatures Resulting from the Mixing of High End-Point Gasoline and Kerosene Vapors with 15 Times Their Weight of Air at Varying Temperatures

We were very much surprised to find how little heat was taken up when air alone passed through the heating chamber. With a surface more than adequate to vaporize a full charge when the fuel was taken into the heating chamber, if air alone were passed through the heating chamber, the fuel being taken into the airstream beyond the heating chamber, the temperature was only from 10 to 20 deg. fahr. above that of the entering air and the engine ran very poorly indeed, with every evidence of poor fuel-distribution. Another evidence of this point is that, at a speed and load at which the temperature of the heating plate was 400 deg. fahr. with no circulation above it, when the air alone for the engine was taken over the plate, the plate temperature fell 30 deg. fahr.; but, when both the air and fuel charge were sprayed on the heating surface, its temperature fell 150 deg. fahr., or five times the temperature drop when air alone was passing. Observation of thermocouples at various points of the heating surface showed that the air received most of its heat in making the right-angle bend to flow across

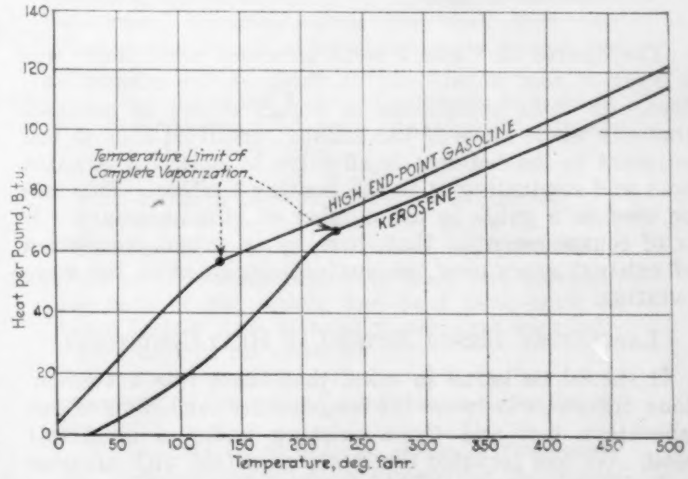

Fig. 11—Sensible Heat of High End-Point Gasoline and Kerosene at Varying Temperatures in a 15 to 1 Air-Fuel Mixture

the metal surface, and that there was very little heat-transfer beyond the bend.

Since the liquid fuel on the heating surface is at no higher temperature than at its boiling-point, while the surface is hotter than this, it seems reasonable to believe that the communication of heat directly from the liquid fuel to the air might almost be ignored.

The test heating-chamber was constructed so that the area of surface exposed could be varied as necessary to maintain a constant mixture-temperature at varying speeds and loads. We were pleased to find that a constant area of surface was required for any given fuel, at both low and high speeds, at wide-open throttle; and that the area of surface which was right for wide-open throttle, was adequate for part-throttle running. An exception to this rule has already been noted in that, when the temperature of the plate fell below the boiling-point of the fuel, considerably more surface was needed.

Under the conditions of our test, the area of surface presented to the fuel, as found adequate for creation of a dry fog, is given in Table 2. For idling with kerosene and alcohol, a surface approximately 40 per cent greater than is given in Table 2 seemed necessary when the fuel was spread out in a thin film.

TABLE 2—ADEQUATE HEATING SURFACE FOR EACH SPECIFIED VOLUME OF ENGINE PISTON DISPLACEMENT

Kind of Fuel	Adequate Heating Surface, Sq. In.	Engine Piston Displacement, Cu. In.
Motor Gasoline	1	6.5
Aviation Gasoline	1	11.5
Kerosene	1	4.5
Grain Alcohol	1	5.6

Under some conditions the surface collecting heat from the exhaust is a limiting factor of hot-spot capacity. In our experiments the surface presented to the exhaust was approximately three times that presented to the intake, giving the ratios of exhaust surface to piston displacement that are presented in Table 3.

TABLE 3—ADEQUATE EXHAUST SURFACE FOR EACH SPECIFIED VOLUME OF ENGINE PISTON DISPLACEMENT

Kind of Fuel	Adequate Exhaust Surface, Sq. In.	Piston Displacement, Cu. In.
Low-Test Motor-Gasoline	1	2.2
Aviation Gasoline	1	4.0
Kerosene	1	1.5
Grain Alcohol	1	1.9

The figures in Table 3 were obtained when there was a layer of soot about 1/32 in. thick on the exhaust surface. In their application to design it can be assumed that the whole mass of the exhaust manifold around and adjacent to the hot-spot is effective in collecting exhaust heat and conducting it to the heating surface. This can be used as a guide to the number of ribs necessary. It is of course essential that there be an actual circulation of exhaust gases over the surfaces included in the computation.

Laboratory versus Motor-Car Heat-Conditions

It should be borne in mind that there was a tremendous difference between the temperature conditions of our laboratory test and those existing under a motor-car hood. We had jacketed the intake-manifold with asbestos and placed asbestos shields between it and the exhaust pipe so that there was no radiation of heat from the exhaust manifold to the intake. We had a fan blast on the intake system so that the temperature was that of the room, 75 to 85 deg. fahr. instead of the 140 to 160-deg. fahr. fan-blast temperature that, in summer, is ordinarily directed onto the intake system under the hood; we also held the water temperature of the engine at 140 deg. fahr., which is somewhat lower than that of many engines when pulling a heavy load. The only heat applied to the mixture was at the heating surface.

When a hot-spot is applied to an intake system that has a long extended surface in proximity with the exhaust manifold, or one in which a large part of the intake passage is jacketed in the cylinder-head, there is bound to be a tremendous difference between the mixture temperatures of summer and winter operation, although no greater difference than would exist in mixture temperature without the hot-spot. If, in addition, the air enters the carbureter at 140 to 160 deg. fahr. in summer, and between zero and 40 deg. fahr. in winter, it is obvious that some sort of temperature regulation will be needed. But it would seem logical to place the control where the variation occurs, on the hood temperature or on the air entering the carbureter, rather than on the hot-spot, the temperature transfer of which varies very little between all seasons and conditions of operation. Indeed, thus far we know of no completely successful effort for correcting for atmospheric and seasonal temperature-changes of the intake system by change of the heat application at the hot-spot.

While on the subject of power loss from too much heat applied to the intake charge, it can be stated that the loss from expansion of the charge is less than is generally believed, and that the extreme and remarkable lack of power noted with some engines when there is too much heat on the manifold is due to a condition of detonation rather than the loss of so-called volumetric efficiency.

The Separating Hot-Spot

It is well known that many of the shortcomings now experienced with present hot-spots are due to the fact that the fuel does not stay on their heating surfaces long enough to be subjected to complete vaporization and conversion to a fog. The result is that the operation of the engine is efficient and correct only above certain limiting mixture-temperatures. The obvious step seems to be to incorporate with the heating surface a separator that will catch the unvaporized fuel-drops and return them to the heating surface. We have found that very good results can be obtained with such a device, but it is essential that the separating hot-spot have *adequate capacity for transmitting heat from the exhaust to the fuel;* otherwise there will be a time when the fuel, although metered in the carbureter, will stop and collect in the heating chamber instead of going to the engine, exactly as fuel "loads" in our present intake-manifolds at low air-velocities. But with the current type of intake-manifold, if the supply of vaporized fuel is inadequate to run the engine, it can always be increased by using the carbureter mixture control and raising the engine speed to a point where the air velocity carries a firing charge to each cylinder. With the separating hot-spot, this cannot be done, at least not until the separating chamber is filled with liquid fuel, but it is remarkable how well a passenger-car engine will perform on fuels so heavy that they cannot be vaporized and passed on to the engine except at part throttle. For truck and tractor usage, in fact for all heavy-duty usage, the separating hot-spot, if properly designed, presents the great advantage of abso-

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Duralumin

By R. W. Daniels[1]

Cleveland Section Paper

THE author gives a short history and general description of duralumin and quotes the Navy specification of its physical properties as drawn by the Naval Aircraft Factory. The manufacture of duralumin is described and commented upon, inclusive of an enumeration of the improvement in physical properties produced at each stage. The physical properties are stated for annealed, heat-treated and hard-rolled duralumin and some of the possible automotive applications are suggested, inclusive of wormwheels, bearings, gears, connecting rods, rims and wheel parts and chassis and body trimming.

A report by the research department of the Fifth Avenue Coach Co. on the results of a test it made on duralumin wormwheels is included and the author details the advantages he claims as being attendant upon the usage of duralumin.

DURALUMIN is an aluminum alloy produced after years of systematic search to fill the demand for a metal combining the lightness of aluminum with the strength and toughness associated with ferrous metals. This condition has been met to a remarkable degree and the resulting physical characteristics make duralumin a most desirable material for extensive automotive application. As the commercial manufacture of this metal in this country dates back little more than 2 years, a short history and general description are given to afford a better understanding of the subject, although some information of this character already has been published.

Duralumin was first made in Germany and was developed by A. Wilm and associates during the years 1903 to 1914. The principal and unusual feature of this alloy is that after it has been hot, or hot and cold, worked, it can be strengthened and toughened further from 40 to 50 per cent by heat-treatment. This heat-treatment is somewhat analogous to that of the heat-treating alloy-steels, and consists of quenching from temperatures below its melting point, followed by an aging process. The increased physical properties are not all produced immediately on quenching, but increase during the subsequent aging. In addition to being made in Germany, the manufacture of duralumin was taken up in England by Vickers, Ltd., prior to the late war. During that conflict its use for structural purposes in connection with aviation brought the material before the eyes of the engineering world. To-day duralumin is recognized as occupying the same relative position to ordinary sheet or bar aluminum that heat-treated alloy-steel does to ordinary carbon-steel.

Duralumin is an aluminum alloy containing copper, manganese and magnesium. Its strength and toughness are comparable with those of mild steel, and are obtained with a specific gravity of 2.81 as against 7.80 for steel. The melting-point is approximately 655 deg. cent. (1211 deg. fahr.), the recalescence-point is 520 deg. cent. (968 deg. fahr.), the annealing temperature is approximately 360 deg. cent. (680 deg. fahr.) and the coefficient of expansion is 0.0000225 per degree of temperature centigrade (1.8 deg. fahr.). The chemical composition of the alloy varies within the following limits: copper, 3 to 5 per cent; magnesium, 0.3 to 0.6 per cent; manganese, 0.4 to 1.0 per cent; and the remainder is aluminum plus impurities. Small quantities of other metals are added sometimes for certain specific reasons. For instance, chromium can be added to increase the burnishing qualities of the metal.

The relative modulus of elasticity of duralumin is about one-third that of steel. The Bureau of Standards gives its value as being between 10,000,000 and 11,000,000 lb. per sq. in. Steel is quoted generally as having a modulus of elasticity of 29,000,000 lb. per sq. in. As the physical properties that can be obtained commercially from duralumin have not had much publicity, the following specification, as drawn up by the Naval Aircraft Factory, is of interest:

Material Specification for Duralumin

Use.—This specification is drawn to cover the requirements of duralumin sheet, rods and wire supplied to the Naval Aircraft Factory

General.—General specifications for the inspection of material, issued by the Navy Department, in effect at date of opening of bids, shall form part of this specification

Material.—This alloy shall show upon analysis the following chemical content:

	Percentage
Copper,	3.5 to 4.4
Magnesium,	0.2 to 0.75
Manganese,	0.4 to 1.0
Aluminum, minimum,	92.0 ..

Specimens for analysis or test shall be taken from the sheet, rod or wire selected as provided by the inspector

Manufacture.—No scrap shall be used other than that produced in the manufacturer's own plant and of same composition as the material specified

Workmanship and Finish.—The sheets must be of uniform quality; they must be sound, smooth, clean, flat and free from buckles, seams, slivers, scratches and other defects

Material in which defects are revealed by manufacturing operations shall be replaced by the manufacturer, notwithstanding the fact that the sheets, rods or wires have previously passed inspection

Physical Properties and Tests.—Duralumin is to be in the heat-treated condition. Its physical properties are to be as follows:

Specific Gravity, 2.80 to 2.85
Yield-Point in Tension, lb. per sq. in., 25,000
Tensile-Strength, lb. per sq. in., 55,000
Modulus of Elasticity, lb. per sq. in., 9,400,000

Selection of Test-Specimens.—At least one specimen for each of the tensile and bend tests shall be taken from a sheet selected to represent each individual melt of the material

The material shall be furnished in the annealed, quenched or "as-rolled" condition, as specified in the order

When material is ordered either in "quenched" or "as-rolled" condition, specimens for the tensile and bend tests shall be tested in the quenched condition. When material is ordered in the annealed

[1] A.S.A.E.—Baush Machine Tool Co., Springfield, Mass.

condition, specimens for the tensile and bend tests shall be treated in both the physical condition in which the material is received and also in the quenched condition

Specimens for the tensile and bend tests shall be prepared in accordance with the General Specifications for Inspection of Material issued by the Navy Department, except that the form of test-specimens shall be as shown in a sketch to be obtained upon application to the Naval Aircraft Factory

Tensile-Strength.—Tensile test-specimens cut in any direction from the sheets must have the properties specified in Table 1

TABLE 1—TENSILE TEST REQUIREMENTS

Physical Condition	Property	Sheets or Strips 0.05 In. Thick or Less Minimum	Maximum	Sheets or Strips Over 0.05 In. Thick Minimum	Maximum
Annealed	Ultimate Tensile-Strength, lb. per sq. in.	25,000	38,000	25,000	38,000
Annealed	Elongation in 2 In., per cent	10		10	
Quenched[2]	Ultimate Tensile-Strength, Minimum, lb. per sq. in.	55,000		55,000	
Quenched[2]	Yield-Point, Minimum, lb. per sq. in.	25,000		25,000	
Quenched[2]	Elongation in 2 In., per cent	18		18	

[2] Quenched specimens shall not be tested within 4 days after completion of heat-treatment. Annealed specimens shall be tested within 12 hr. after treatment.

Bend Test.—Specimens cut in any direction from sheets either annealed or quenched must withstand bending cold through an angle of 180 deg. over a diameter equal to four times the thickness of the sheet, without cracking

Dimensions and Tolerances.—The sheets shall be shipped in the lengths and widths called for in the order. The tolerances given in Table 2 will be allowed on the thickness of the sheets.

TABLE 2—ALLOWABLE TOLERANCES FOR SHEETS NOT WIDER THAN 18 IN.

Normal Thickness, in.	Tolerances, in.
0.0808 and more	±0.005
0.0808 to 0.0359	±0.003
0.0320 or less	±0.001

In duralumin forgings where the sections are heavy, it is advisable to lower the minimum tensile-strength requirements to 50,000 lb. per sq. in.; a proportional increase in elongation will be found. Duralumin is unaffected by mercury, is non-magnetic, withstands atmospheric influences and offers a remarkable resistance to sea and fresh waters. It is affected only slightly by numerous chemicals which, in the ordinary way, corrode other metals and alloys so readily; it does not tarnish in the presence of sulphureted hydrogen; and it takes a polish equal to nickel-plating and remains bright without cleaning longer than any plated or silvered article. It is the ideal substitute for aluminum, German silver, brass, copper, nickel-plated and silvered articles, and is the only substitute for steel where lightness combined with the strength of that metal is required. It is the only light metal that can replace steel in forgings, with a two-thirds saving in weight. Heat-treated duralumin forgings approximate mild-steel forgings in strength. Wherever weight is a deciding factor, duralumin is the most satisfactory metal for most shapes made by hot-working or forging. Naturally, duralumin forgings are especially desirable for reciprocating or moving parts where inertia, due to their own weight, forms a large part of the total stress. Duralumin machines and polishes very easily and, as it does not rust or corrode, it can be used in many places where weight is not the prime essential.

The manufacture of duralumin is somewhat analogous to that of steel and, in brief, is as follows:

(1) Manufacture of the alloy from its aluminum base
(2) Casting the ingot
(3) Hot-rolling or cogging in blooms, billets or slabs
(4) Hot or cold-working to final shape
(5) Heat-treating

The ingots are poured at as low a temperature as is practicable; that is, just enough above the melting-point to fill the mold and prevent cold-shuts. The ingots are then either hot-rolled or cogged into slabs, blooms or billets, similar to the manner of working steel. This hot-working is done at a temperature of from 450 to 480 deg. cent. (842 to 896 deg. fahr.), and care must be used not to perform any work on the metal above these temperatures because there is a danger of hot-shortness if the material is rolled or forged at higher temperatures. It is seen readily that such low temperatures cannot be judged by color; therefore, it is necessary to use accurate pyrometers in heating the metal, previously to working. The final rolling or forging can be done hot or cold, according to the character of the work being handled or the nature of the shape it is desired to produce.

The hot or cold-worked metal in its final shape shows greatly improved physical properties over those of the cast ingot, but the full development of its qualities is obtained only by a specific heat-treatment. To obtain this heat-treatment, the metal is heated to a temperature of 500 to 520 deg. cent. (932 to 968 deg. fahr.) for a period of time, depending upon the section of the piece, and immediately quenched. The heating and quenching immediately start to improve the physical qualities of the metal, but the maximum results are obtained only by the subsequent aging. During the aging period, which takes from 1 to 5 days, the alloy markedly increases in tensile-strength, hardness and elongation. Aging is sometimes accelerated by placing the metal in a hot-water bath up to 100 deg. cent. (212 deg. fahr.), or in a hot room. The above heat-treatment develops the remarkable properties possessed by duralumin, and these properties have not been obtained in like degree in any other aluminum alloy.

Improvement of Physical Properties

The various stages of manufacture, as related, increase the physical properties of duralumin by distinct steps. The cast ingot shows a tensile-strength of from 28,000 to 32,000 lb. per sq. in., with an elongation in 2 in. of from 1 to 3 per cent. The hot or cold-worked metal shows a tensile-strength of from 40,000 to 50,000 lb. per sq. in., with an elongation of from 6 to 12 per cent. These last figures are variable, depending upon the amount of working in the cold state. Upon subsequent heat-treatment and aging, the physical properties of duralumin show a marked increase, namely, 55,000 to 65,000 lb. per sq. in. tensile-strength and an elongation of from 18 to 25 per cent.

When it is required to put a considerable amount of work upon duralumin in its finished state, it often is found necessary to anneal the sheets between operations in precisely the same manner as in handling other metals. This annealing should be done at 350 deg. cent. (662 deg. fahr.). If several drawing operations are to be per-

formed, it may be necessary to anneal the metal between such operations. Annealed duralumin can be heat-treated and the maximum physical properties obtained, no matter what the shape or form to which the metal may be reduced. Conversely, heat-treated duralumin can be annealed.

Duralumin can be cold-worked after heat-treatment and aging. This operation produces a hard, smooth finish and materially increases the tensile-strength of the metal at the expense of elongation; that is, the tensile-strength will increase from 6000 to 10,000 lb. per sq. in. over that of the heat-treated metal, but the elongation may drop as low as 3 or 4 per cent.

In the annealed form it can be drawn, spun, stamped or formed into a great variety of shapes, as is the case of brass and mild steel. The physical properties in this state average as follows:

Ultimate Tensile-Strength, lb. per sq. in.,	25,000 to 35,000
Elongation in 2 In., per cent,	10 to 14
Brinell Hardness	54 to 60
Scleroscope Hardness	9 to 12

Duralumin in its heat-treated form can be slightly shaped or formed and can be bent cold to 180 deg. over a mandrel four times the thickness of the sheet. Its remarkable tensile-strength is here combined with its maximum elongation as follows:

Ultimate Tensile Strength, lb. per sq. in.,	55,000 to 62,000
Yield-Point, lb. per sq. in.,	30,000 to 36,000
Elongation in 2 In., per cent,	18 to 25
Brinell Hardness,	93 to 100
Scleroscope Hardness,	23 to 27

Heat-treated duralumin forgings have similar physical properties. Heat-treated and hard-rolled duralumin is used where no bending or forming is required. It is a very hard, strong, springy metal in this state and machines or polishes beautifully. Its physical properties in this form average as follows:

Ultimate Tensile-Strength, lb. per sq. in.,	67,000 to 72,000
Yield-Point, lb. per sq. in.,	55,000 to 65,000
Elongation in 2 In., per cent,	3 to 8
Brinell Hardness,	130 to 140
Scleroscope Hardness,	37 to 42

Having covered the general characteristics of the metal, a more intimate discussion of a few of the many automotive applications is given. Some of these applications are still under experimental observation and, in others, duralumin has been adopted as a standard material.

Automotive Wormwheels and Bearings

During the past 2 years much experimental work has been done along this line and the data are now available. Since the characteristics of the metal brought out in this class of service are highly desirable in other forms of gearing, bushings and the general replacement of bronze, these data are given at some length.

From the general description of duralumin it will be seen readily that here is an ideal material for wormwheels, provided the bearing or wearing qualities are satisfactory. For a given section, the weight is one-third that of the conventional bronze. The tensile-strength and the relatively high elastic-limit assure superior tooth-strength. The homogeneous structure and uniform hardness of heat-treated duralumin forgings obviate hard spots, porosity and spongy areas so common in bronze castings, entailing not only machining losses but uneven tooth-wear in service. The excellent machining qualities assure the manufacturer a saving in the machining costs, compared with those of bronze.

The wearing qualities of wormwheels for automotive purposes is best determined by actual road service, as bench or laboratory-test results do not always correspond. It is instructive, however, to compare results obtained from duralumin with those of other materials under identical conditions. The data from various laboratory tests under my observation on bronze and duralumin wormwheels can be summarized by saying that tests destructive to duralumin wormwheels were also destructive to those made of bronze. The results are always good where duralumin and hardened steel are run together. An example of this application is shown by duralumin connecting-rods running direct on the wrist-pins with better life at this point than with the conventional bronze-bushed connecting-rod of equal bearing area.

Comparative tests of bearings made from duralumin against bearings made of genuine babbitt metal show that, for shaft speeds exceeding 700 r.p.m. and loads over 200 lb. per sq. in., duralumin bearings develop less friction, remain cooler and show practically no loss in weight under the most severe conditions. For lower bearing pressures and slower speeds, babbitt metal is superior. Table 3 shows the details of this test.

TABLE 3—COMPARATIVE BEARING TEST

Loads, Lb. per Sq. In.	Speed, R.P.M.	Total Number of Revolutions	Final Temperature Deg. Cent.	Final Temperature Deg. Fahr.	Rise in Temperature Deg. Cent.	Rise in Temperature Deg. Fahr.	Friction, Lb.	Loss of Weight Grams
Baush Duralumin, Grade B								
100	632	37,920	39	102	18	64	21.15	.....
200	625	37,500	71	160	70	158	42.30	(*a*)
300	629	37,740	54	129	32	90	63.45	.....
400	623	37,380	62	144	39	102	84.60	(*b*)
Genuine Babbitt, Bureau of Standards								
100	694	12,230	89	192	53	95	22.00	0.023
200	706	16,510	102	216	58	104	29.00	0.021
300	686	15,150	125	257	100	180	38.00	0.013(*c*)
400	603	5,500	139	282	94	169	79.00	0.054(*d*)

(*a*) Bearing roughed and ran warm in 10 min.
(*b*) No measurable loss of weight
(*c*) Belt slipping
(*d*) Bearing seized, smoking

In regard to road tests, a considerable number of duralumin wormwheels are now actually in regular service in trucks ranging from 1 to 3½-ton capacity. These wheels have been in service from a few weeks to over 2 years without any failure. As these wheels are all running, complete data are not available, but through the courtesy of G. A. Green, vice-president and general manager of the Fifth Avenue Coach Co., New York City, I quote from the report of one of its preliminary tests under date of Aug. 2, 1921, as follows:

FIFTH AVENUE COACH CO. REPORT

General.—The greatest possibility of effecting weight-saving lies in the employment of aluminum or some of its alloys. With this idea in mind it was decided to test in road service a rear-axle wormwheel fabricated from an aluminum alloy commercially known as duralumin

Object.—To determine by road test the merits of a duralumin wormwheel, especially noting its resistance to wear, relative weights and the like, as compared with the standard bronze unit

Description.—Duralumin is a light aluminum-alloy having a specific gravity of 2.82. It can be forged, stamped, drawn or spun. The product is highly resistant to corrosion. The metal is heat-treated by the producer in a manner that is not made public. The following physical properties are claimed for this material:

Tensile-Strength, lb. per sq. in.,	55,000
Elastic-Limit, lb. per sq. in.,	30,000
Elongation in 2 In., per cent,	18

Bend cold over 180 deg. on a mandrel four times the thickness of the sheet.

A wormwheel was cut having standard pitch and ratio. The relative weights are, for duralumin, 15.0 lb.; and for standard bronze, 41.5 lb. The difference, 26.5 lb., is the equivalent of 64 per cent

Method.—Three duralumin wormwheels were procured from the Baush Machine Tool Co., and installed in standard worm-carriers. The road test was started on three 2A-type buses. An inspection of these parts was made periodically for the first few weeks of service and again during the next annual overhaul of these buses

Results.—The results obtained with these sample wormwheels are recorded in the following tabulation:

Bus Number	30	39	40
Date Installed	Aug. 27, 1920	Sept. 15, 1920	Sept. 11, 1920
Date Removed	June 20, 1921	In service	June 17, 1921
Mileage	26,672	24,143	32,253
Fuel Average, miles per gal.,	6.75	6.52	6.65

From the above tabulation it will be noted that a total distance of 83,068 miles has been covered with these units, all of which show excellent resistance to wear along the pitch-line at the end of this period. In one case the unit removed from bus No. 40 had a bearing failure behind the worm. The sides of this worm were slightly chipped, but not sufficiently to prevent returning it to service with the others

Conclusion.—Inspection of these parts after the above stated amount of service indicates wearing qualities equal to those of the standard bronze wormwheel. In view of the advantages to be obtained from the use of this material it is recommended that several more be obtained for a more exhaustive test

After long tests with bronze wheels where the oil has not been changed, the oil is found to contain particles of bronze in suspension. This condition is very marked in some tests, and is of importance not alone as indicating tooth wear but as showing the deterioration of the lubricating value of the oil. Oil heavily charged with metallic particles acts more like an abrasive than a lubricant and is an important factor in automotive worm-gear wear, because the oil is seldom renewed as often as is desirable. When duralumin wheels were used, the charging of the oil with metallic particles was practically negligible. As brought out by these tests, indications point to excellent life as well as lightness for duralumin wormwheels, unless the wheels have been roughened by lack of lubrication or too high a tooth-pressure, which will injure or destroy any worm gearing.

Gears

The same qualities that make duralumin a desirable material for automotive wormwheels make it valuable for plain spur and other gearing. It is suitable for this class of work where the pressures are sufficiently within its elastic-limit of 30,000 lb. per sq. in. Where this condition is met and light weight and quietness are desirable, it replaces iron, steel, brass, fiber, fabric and the like. Where duralumin can be run against steel rather than against itself, the best results are obtained. The outstanding automotive application is found in the timing-gear trains of automobile engines where both long life and quietness are essential.

Helical-cut spur-gears of duralumin, alternated with steel gears, have been most successful in service. Detailed test reports are not especially interesting as the gear design varies with every engine, but the fact that upward of 80,000 duralumin camshaft and idler gears are now in use is conclusive. It may seem somewhat paradoxical that duralumin gears, when meshed with steel gears, are quiet, because all duralumin forgings are resonant when struck. The explanation is undoubtedly in the difference in pitch of the sound vibrations of steel and of duralumin. This, of course, applies only when the mass and section of the duralumin gear are properly proportioned to the steel gear.

Connecting-Rods

Reciprocating and other high-speed parts naturally offer a field for duralumin forgings or shapes, and their performance under alternating stress has proved highly satisfactory. Duralumin connecting-rods give remarkable results in high-speed engines, especially in connection with aluminum or other light-weight pistons. Much experimental work has been and is being done, the data being beyond the scope of this paper; the work really comes under the heading of the effect of light reciprocating parts on engine design. However, it is safe to state that duralumin connecting-rods can replace steel connecting-rods, while retaining the same outside-diameter dimensions.

It is recommended that the radii and sections be somewhat increased, depending upon the characteristics of the steel replaced. However, such a large part of the stress on a connecting-rod is due to its own weight and that of the piston that a considerable sacrifice of tensile-strength is allowable to the duralumin connecting-rod due to the weight saved on the rod. The average I-beam-section steel connecting-rod generally weighs about twice as much as the duralumin connecting-rod that can replace it. The piston-pin can be floated directly in the duralumin connecting-rod but, except in special cases, it probably will be desirable to babbitt the lower end.

Other Parts

One of the most satisfactory applications of duralumin to the automobile is that of the rim and other wheel parts. Here the engineer is not only appreciably reducing the unsprung weight and cutting down the centrifugal action of the wheel, but is giving the owner-driver something he can see and appreciate. First, the minimum saving of 10 lb. for the rim alone is welcome in tire-changing. Second, the non-rusting or non-corroding characteristic of duralumin allows the rim always to function properly and prevents the tire from rusting and vulcanizing to the rim. These advantages, added to the strictly engineering ones, justify the necessary increase in cost of the change from steel in certain grades of car at least. As the physical properties of duralumin actually exceed those of the 0.10 to 0.15-per cent carbon-steel used in rims, cost appears to be the only drawback. A certain type of disc wheel, with discs and rims of duralumin of the same sections as the steel design, have been subjected to a road test for more than a year with entirely satisfactory results, and much experimental work is now going on.

Duralumin is an ideal material for chassis and body trim that requires a bright finish. Great strength and saving of weight are not of prime importance here. A commercially workable material of pleasing appearance, of high resistance to atmospheric influence or other tarnish and not plated, is wanted. Duralumin forgings, stampings and drawings, especially when supplemented by aluminum-alloy castings of the same color and resistance to tarnish, are being used with satisfaction to replace nickel-plate, brass and steel in such articles as hubcaps, door-handles and instrument-board fittings.

It is obviously impossible in a paper of this character

(Concluded on p. 490)

Motor Cars on Rails

THE Metropolitan Section's trip to New Haven, Conn., via rail motor-cars from New York City, on the occasion of its joint meeting with the New England Section, aroused such a surprising amount of interest that the Section officers made Motor Cars on Rails the subject of discussion at a subsequent meeting. The meeting was opened by the presentation of brief papers by Roy V. Wright, W. L. Bean and L. G. Plant, which are included in the text that follows. Afterward, there was an active discussion of the engineering problems involved in the design, construction and operation of this type of automotive vehicle. The oral discussion at the meeting was supplemented by contributed written discussion from several prominent authorities on this subject, and this supplementary discussion also is printed herewith.

THE FIELD FOR THE RAIL MOTOR-CAR

BY ROY V. WRIGHT[1]

THE author quotes the conclusions reached by the Committee on the Development of Motor Cars for Light Passenger Service that reported to the American Railway Master Mechanics' Association in 1907, and states that they fit the situation with regard to the rail motor-car fairly well as it exists to-day. Mechanical transmission and design are commented upon briefly.

There are certain objections in the public mind in regard to the riding qualities and other matters connected with the rail motor-car; they may be imaginary, but they constitute a real problem. To make a success of rail motor-cars, the idea of using them must be sold to the public.

THE conclusions reached by the Committee on the Development of Motor Cars for Light Passenger-Service, and reported to the American Railway Master Mechanics' Association in 1907, are most interesting. One conclusion is

> That there is a field for the rail motor-car cannot be questioned, its breadth at the present period being limited only by the development of the motor-car power-equipment

The above statement is just as true to-day as it was in 1907. Other conclusions of the committee are as follows:

> Steam, as a motive power, has always possessed a distinct advantage of flexibility of control as well as reliability
>
> The internal-combustion engine, within certain defined limits of horsepower sizes, has been developed to that stage of excellence where these advantages cannot be said to apply exclusively to the steam engine
>
> With the experimental work that is being conducted in the development of the internal-combustion engine, using fuels that cost less than gasoline, and with promising results, who can predict the final outcome of the motive power that will be the most satisfactory from all points of view for the rail motor-car? It is probable that both types will have their distinctive fields, depending upon the availability of the fuel

These conclusions, written 15 years ago, fit the situation fairly well as it exists to-day. However, one great change has taken place since 1907. It is that the highway motor-truck has been developed to a very high degree; and to-day we are approaching the rail motor-car problem from a somewhat different angle. For instance, in the old days it was assumed that if a motor car were to be developed for rail service it must be strong enough and powerful enough to withstand a collision with a steam locomotive or a steam train that might operate on the road at the same time. To-day the tendency, looking at the problem from the highway motor-truck angle, seems to be toward a lighter construction and utilizing, so far as possible, automobile parts that will be interchangeable. This interchangeability is extremely desirable if it can be brought about. One difficulty, and it may be the greatest difficulty, is that the power units used on a highway motor-truck are not large enough to supply the necessary reserve or flexibility that is needed for the various conditions of handling traffic on the rail, either on the feeder lines or on the short lines. Then, too, we have found that many of the automobile companies who are interesting themselves in this problem are thinking in terms of building cars on a quantity production basis, at least so far as the more important parts are concerned; but there are many reasons that lead us to question whether this can be done, at least on any very large scale.

Undoubtedly, for a great many conditions, it will be necessary to develop a special engine considerably larger and more powerful than is now employed on the highway motor-trucks. There is considerable speculation as to just how these larger power units are to be developed. It has been suggested, for instance, that a light Diesel engine will fill the bill in many cases and give the necessary power and flexibility. There are now in service high-pressure steam-cars that do have a horsepower capacity considerably beyond that of the gasoline motor-cars.

Mechanical Transmission and Design

Apparently the limits of mechanical transmission have been very nearly reached, and this means that some other way of overcoming the problem must be found. In some instances in Europe the electrical transmission is used with the Diesel engine. There is a possibility, however, that we may have to consider the hydraulic transmission in connection with these larger power units.

Designing the car to decrease the wind resistance requires special attention. It is a factor that must be recognized and dealt with. Further, we must meet safety requirements to a greater degree than we have met them in the past in designing some of these cars; in some instances, this may affect the kind of power that we shall be able to develop and use.

In regard to the double-end car, it seems to me we must draw the line somewhere and that we cannot expect too much of motor cars. Although we could run a car forward or backward in steam-railroad operation, we usually provided a turntable at the end of a run. It ought to be a simple matter to use those turntables for

[1] Managing editor, *Railway Age*, New York City.

the motor car and, if they are not available, the building of a wye is not an insurmountable obstacle. Possibly we had better solve some of the other problems before we attack the solution of this double-end-car proposition too seriously.

Another thing that we must keep clearly in mind if we want to make a real success of rail motor-cars is that the idea of using them must be sold to the public. There are certain objections in the public mind in regard to the riding qualities and some other things connected with the rail motor-car; they may be imaginary, but they constitute a real problem.

SOME REQUIREMENTS FOR THE RAIL MOTOR-CAR

BY W. L. BEAN[3]

THE rail motor-cars now used by the New York, New Haven & Hartford Railroad are illustrated and commented upon, and statistical data regarding their operation are presented. The features mentioned include engine type and size, transmission system, gear-ratio, double end-control, engine cooling, heating by utilizing exhaust gases and exclusion of exhaust-gas fumes from the car interior. A table gives revenue data.

THE usual steam-railroad coach is heavy. The impacts of that car on the track are sufficient to cause a yielding of the roadbed, track and ties; whereas a light vehicle has little or no effect. The smaller rail-pressures reflect themselves, for instance, in the fact that we have trouble in operating electric cross-ing-signals, particularly on Monday morning when there has been no traffic over the line on Sunday. That is not altogether due to weight, it is a matter of wheelbase and speed; but it shows that the wheel pressure on the rail is so light in relation to what usually operates over the tracks that it is relatively negligible. That has its effects on the riding qualities, yet we must keep the vehicle light to propel it economically with the gasoline engine.

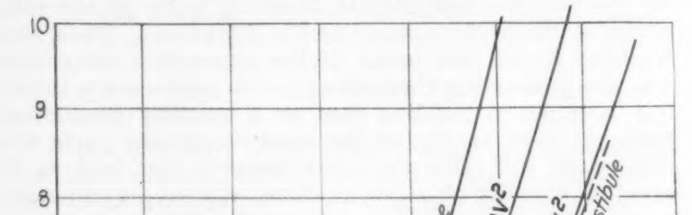

FIG. 1—WIND-RESISTANCE CURVES FOR CARS OF DIFFERENT FRONTAL SURFACES OPERATING AT VARIOUS SPEEDS

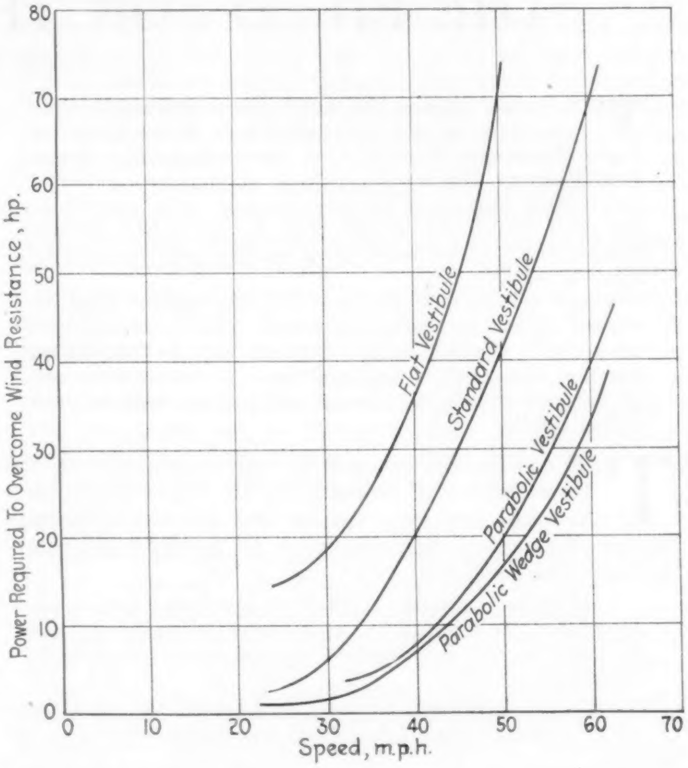

FIG. 2—HORSEPOWER REQUIRED TO PROPEL CARS HAVING DIFFERENT CONTOURS OF FRONTAL SURFACE AT VARIOUS SPEEDS

We think the rail motor-cars now used on the New York, New Haven & Hartford Railroad constitute an exceedingly good beginning and that, as a foundation from which to work, a much better unit can and should be developed. But there is no use in disguising facts. If one will ride in one of those cars for a number of hours, one must admit that the wear and tear on one's nerves is more than in riding on a steam car; and the patrons bring up that proposition. So, while we are working for more power, we need the greater flexibility together with perhaps a six-cylinder engine, because I believe that we should not consider more than six cylinders for some time to come. We must get a six-cylinder engine that is designed for rail motor-car service; this means continuous heavy duty and not a light throttle and drifting,

[3] Mechanical assistant to the president, New York, New Haven & Hartford Railroad Co., New Haven, Conn.

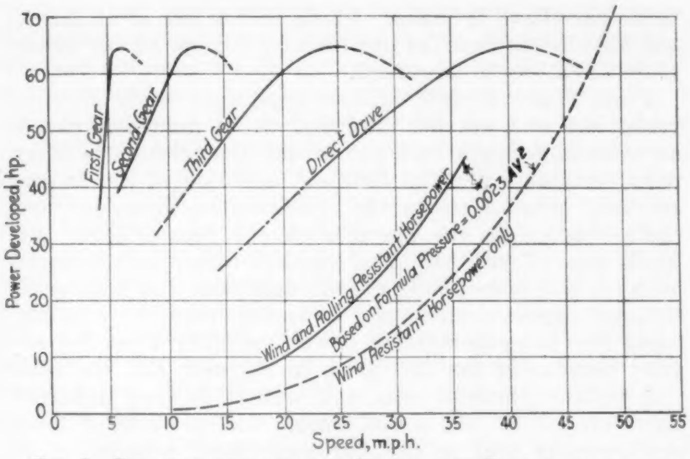

FIG. 3—RELATION BETWEEN THE HORSEPOWER DEVELOPED BY THE FOUR-CYLINDER MACK ENGINE AND THE CAR SPEED

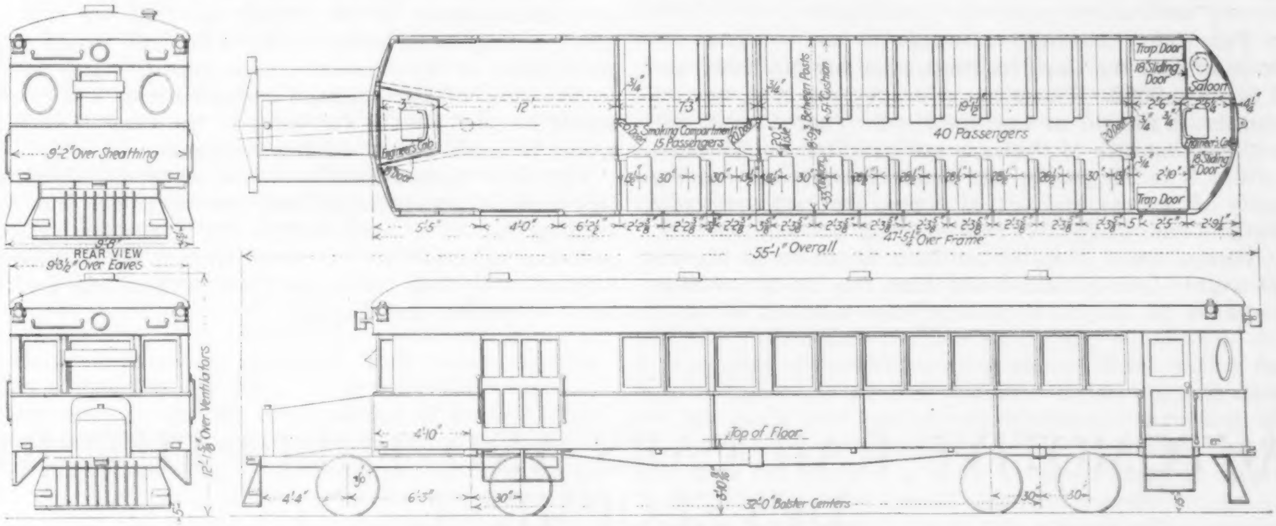

FIG. 4—PLAN VIEW OF A 55-PASSENGER MOTOR RAILCOACH

slowing up for traffic or turning corners. It means full throttle the majority of the time. The engine must be designed for that usage not only from the angle of ability to stand up but with regard to minimum vibration, which of course includes the suspension of the engine. That is important in a rail motor-car because of the sort of drumhead effect given by the roof, floor and sides of the car.

Transmission systems should be designed to permit operating the engine at less than normal speed; that is, at favorable speeds for economy and quietness, when the demand on the engine is less than normal. For instance, a car may drift successfully for 15 to 20 miles down a water-grade. That should be done through a gear-ratio properly adapted; we should be able to let that car drift at less than the full engine-speed. The car may require only power enough to propel it from 20 to 30 or 35 m.p.h. but, if its engine must turn over just as fast as if it were making 35 m.p.h. on the flat, developing a corresponding horsepower, we get conditions of considerable vibration. I think that can be avoided in a measure through the use of proper gear-ratios, and we intend to conduct further experiments with our cars in that direction.

As to the double-end car, I wish we could consider developing cars now without that feature; but the operating requirements in some localities are such that a double-end car would be much superior, from an operating standpoint, than a single-end car. We have terminals on our railroad where a car that could come in and shuttle out would be vastly superior to one that would have to go out to a turntable or a wye; in fact, it would be almost impossible to carry out some of the schedules that are contemplated for such a double-end car, when using a single-end car.

The matter of cooling the engine requires special consideration. We find that the heavy, continuous service requires a greater ability to dissipate heat than in highway cars. The matter of heating by utilizing exhaust gases efficiently and satisfactorily demands considerable study and arrangements that will keep gas fumes outside of the car body are necessary and have not altogether been worked out.

Table 1 gives data covering the revenue service up to recent date. Incidentally, the car had made considerable mileage before that. Under the heading Average Passen-

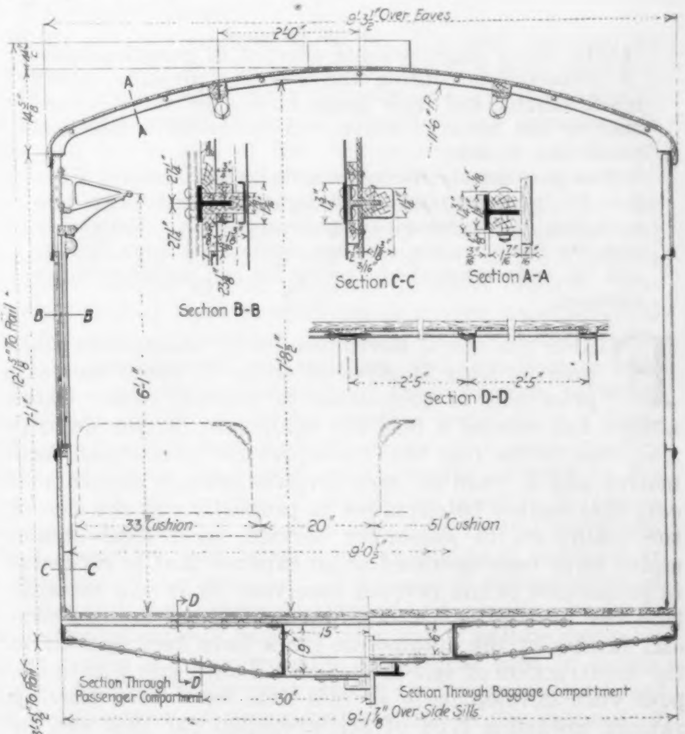

FIG. 5—CROSS-SECTION OF THE BODY OF A 55-PASSENGER MOTOR RAILCOACH

TABLE 1—STATISTICAL DATA ON GASOLINE-DRIVEN RAIL MOTOR-CARS

Items		Car No. 9,000[a]	Car No. 9,001[b]	Car No. 9,002[c]
Placed in Service, 1922		Jan. 4	Jan. 18	Jan. 30
Daily Total, miles		146	59	139
Total Mileage to May 6, 1922		12,441	5,479	10,396
Number of Revenue Passengers to May 6, 1922		11,115	6,822	11,013
Average Number of Passengers per Trip	Revenue	20.0	19.6	39.6
	Non-Revenue	8.5	3.8	3.6
	Total	28.5	23.4	43.2
Total Number of Trips		533	366	301
Total Delay during Period, min.		213	340	179
Total Delay per Trip, min.		0.4	0.9	0.6
Number of Stops per Day		42	12	25
Car Trips Replaced by Steam Train		3	10	25
Number of Trips per Day		6	4	4
Average Speed, m.p.h.		23	25	20

[a] Operated between Derby, New Haven and New Hartford, Conn.
[b] Operated between Fairhaven and Tremont, Mass.
[c] Operated between Litchfield, Danbury and Waterbury, Conn.

gers Per Trip, the total average of non-revenue and revenue is 28.5 for Car No. 9000, 23.4 for No. 9001 and 43.2 for No. 9002. Those are averages per trip, not the maximum on the car at any one time. Therefore, it will be noticed that two of the cars are handling on the average from 3 to 12 people less than the nominal seating capacity of the car and yet, at times, the cars are badly crowded. The delays per trip are 0.4, 0.9 and 0.6 min. The average speed in miles per hour is shown at the extreme right; in most cases the cars run on an average from 35 to 38 m.p.h., because of the number of stops those cars have to make. I rode in one car at 42 m.p.h., but that is too fast for comfortable riding, so far as engine vibration is concerned.

Figs. 1 and 2 show studies that were made of wind resistance and are not intended to be anything except an attempt to show in a rough way the relation between wind resistance and the different contours of the frontal surface. Fig. 3 shows the horsepowers developed and their relation to the speed with the four-cylinder AC Mack type of engine. The vertical distances measured between the horsepower curves represent the rolling-resistance approximately, and it is important to note the rapid rise in proportionate power resulting from the engine, because of the fact that, in the unit car, the relation between frontal area and weight is very different from what it is in a steam train. The problem of wind resistance is real in unit-car resistance, whereas it is decidedly minor in steam or heavy electric types.

Fig. 4 shows approximately our idea of the floor area and arrangement of the larger car that we feel would cover a very substantial field. That car would seat 15 passengers in the forward compartment, which would be in the rear of the baggage compartment, and the seats would be used by the smokers; in the rear of that there would be seats for 40 other passengers.

Fig. 5 is a cross-section of the car body, showing the lightness of construction that one must get into in designing bodies to keep within the power limitations of gasoline engines. At the same time it would give some insulation to help solve the heating problem and eliminate vibration and noise.

AUTOMOTIVE RAIL-CARS AND THEIR FUTURE DEVELOPMENT

BY L. G. PLANT[3]

THE many improvements effected in gasoline-engine construction during the war for airplane, heavy truck, tractor and tank usage have done much toward making the gasoline-driven rail motor-car a practical possibility to-day.

The gasoline-electric cars built by the General Electric Co. are mentioned and light rail motor-car construction is discussed in general terms. Reliability and low maintenance cost are commented upon briefly, and the requirements of service for rail motor-cars are outlined.

FROM the start, developments in automotive engineering have inspired attempts to adapt the same principles of propulsion to railroad cars. There always has existed a field for equipment of this description, due to the fact that the operation of a steam locomotive and a train of cars involves certain elements of cost that cannot be curtailed in proportion to the size of the train; so, in passenger service, light local steam-trains have been operated at an expense that is excessive in proportion to the revenue received. It is only recently that the most vital factors contributing to the commercial success of the automobile truck have been applied in the construction of self-propelled rail-cars, but within the past year developments in this field have been moving rapidly toward a type of self-propelled car that can be substituted successfully for a steam-train in certain classes of service. No recent development in railroad equipment has aroused such universal interest on the part of manufacturers and nearly all railroad departments within a short space of time. The successful adaptation of automotive principles to railroad cars will, I believe, prove a very great benefit to the railroads in enabling them to reduce the cost of light local passenger-service and increase their gross revenue by augmenting and improving the character of this service.

In view of these circumstances, the question arises as to why previous developments in this direction have not met with more permanent success, and it is still something of a mystery why so obvious a solution of the problem as is found in the modern rail motor-car should not have been discovered earlier. But, before discussing the more fundamental causes that retarded this development, it is pertinent to say that our railroads have never been more severely pressed to devise operating economies than within the past year and have never been more keenly alive to the possibilities of any equipment designed to reduce operating costs. Coincident with this attitude, the situation with the truck builders has also been propitious for progress in this direction.

During the period of the war, self-propelled rail-car construction came to a standstill, and many of the cars previously purchased by the railroads were withdrawn

[3] Associate editor, *The Railway Review*, Chicago.

from service, due to their high maintenance-cost and unreliability in operation; but, while the war apparently retarded development along this line, in reality the many improvements effected in gasoline-engine construction, designed not only for airplane use but for heavy trucks, tractors and tanks, have done much toward making the gasoline rail motor-car a practical possibility to-day. In distinction from the relatively slow-speed heavy engines used originally in the McKeen and Hall-Scott cars, we now have in the heavy-duty truck-type of engine a very much lighter high-speed engine capable of exerting a high torque through a wide range of speeds. This has an important bearing on rail-car construction, not only on account of the reduced overall weight of the engine but because the reduced weight of the reciprocating parts obviates the difficulties occasioned in the earlier cars by the inertia of the heavy engine parts. This will account for some of the difficulties encountered on the earlier types of rail car which, although they may appear somewhat crude in the light of present-day practice, represented a real mechanical achievement at the time of their construction.

This is illustrated best in the construction of the gasoline-electric cars built by the General Electric Co. involving the design of a special gasoline engine with two sets of four cylinders each, forming the V-type arrangement that has since been used extensively and indicating that, at the time these cars were first built, they embodied the most advanced engine construction available. Now, however, the variable-speed characteristics developed in engines of the type now considered for gasoline-rail-car operation, together with the variable speed-ratios in the transmission mechanism employed with these engines, afford an element of flexibility in speed control that obviates the necessity for the interposition of electric drive from the standpoint of speed control; and it is believed that the additional weight and first cost involved in an electric generator and motors preclude the economical use of this form of transmission in rail motor-cars of the type now under consideration.

Light Rail Motor-Car Construction

It is apparent, therefore, that from the standpoint of the motive-power unit, the type of rail motor-car now discussed is fundamentally different from that developed prior to the war and represents a distinct advance over these earlier cars. But while the development of light high-speed gasoline-engines capable of operating continuously under heavy loads has been advancing rapidly, there also has been under way a development, inspired partly by what the automobile builders have accomplished through the use of alloy-steels and also by the trend in street-railway-car construction toward lighter weight, such that the builders of this equipment are now able to design very light cars for operation where the power limitation is severe. One of the most remarkable examples of this construction is a double-truck car-body weighing 11,000 lb. that has seating capacity for 46 passengers. This car is 42 ft. long and has a baggage compartment. Broadly speaking, therefore, it can be said that the modern rail motor-car is the embodiment of an improved powerplant and refinement in car construction.

While it is believed that in the numerous designs of self-propelled rail-car in service or under construction there is available to any railroad a type that it would be justified in buying at present, it is admitted that the design of these cars is still in a progressive state principally with respect to details in construction that will insure their reliability and low cost from a maintenance standpoint, and also with respect to increasing the capacity of the equipment. It is not possible to determine from the figures now available the largest number of passengers that can be handled more economically in self-propelled rail-cars than in a steam-train and, of course, this figure would depend upon local conditions, but it is safe to say that under ordinary circumstances, the operation of self-propelled cars with as many as 80 passengers would show a considerable saving over a steam-train carrying the same number of passengers.

Although the question of using trailers or a single large car would need to be decided in this connection, this is not regarded as fundamental to the solution of the problem that, in reality, lies in the design of a motive-power unit of sufficient capacity without sacrificing any of the characteristic features in commercially available types. From a theoretical standpoint, the use of a motor car and trailers in place of a single large car will increase the frictional resistance and dead-weight per passenger slightly; but, practically, operating conditions peculiar to the railroad on which this equipment is operated will prove the determining factor, so that it would be a mistake for any manufacturer who is looking toward the development of greater carrying-capacity in this type of equipment either to depend entirely upon the use of trailers or to commit himself to a design that would preclude the use of trailers.

The application of more power to self-propelled cars presents a real problem, since there are few commercially available engines of the type adapted to this service that exceed 60 hp. at normal speeds. It is in this connection that the unit steam-car has an unique advantage, since it is capable of developing as much as 300 hp. with a flash type of boiler. While it is understood that the unit steam-car has some very special advantages in connection with the subject of self-propelled cars, it is recognized that this type has reached a more advanced stage in relation to its ultimate development than the gasoline-engine car, so that further discussion of this subject will be confined to the latter type which must still be regarded as being in a formative stage.

With gasoline engines of 60 hp., the best that can be anticipated appears to be a car that will seat approximately 40 passengers, carry baggage and operate normally at a speed of about 40 m.p.h. To effect any considerable increase in the size of this car or render it capable of pulling a trailer at the speeds required in main-line service will necessitate more power, either through the use of a larger engine, which ordinarily involves special and expensive construction, or the use of two engines, which involves certain special problems in their control. Assuming that it were practicable to design an individual transmission of sufficient flexibility to enable the simultaneous operation of both engines, and that it were possible to control the operation of these engines satisfactorily, the use of two 60-hp. engines would have a theoretical advantage over a single engine of larger capacity since, whenever the power requirements dropped to the capacity of one engine, it would be possible to run a single engine at full capacity and thus realize more efficient operation than when a larger engine is operated at a fraction of its capacity. The gasoline consumption of a rail motor-car seating 40 persons and carrying baggage will approximate 0.2 gal. per mile, and it will be desirable to maintain a proportionally economical rate in larger cars. Another factor that should encourage development in the direction of using two engines is the element of reliability afforded by two independent driving engines since, ordinarily, one engine will continue to operate

should the other fail. Probably no other factor proved so discouraging to the successful use of both the McKeen and the General Electric Co. cars than engine failures encountered in the operation of this equipment.

Reliability and Low Maintenance Cost

Reliability and low cost from a maintenance standpoint as already referred to undoubtedly constitute the most difficult problems with which designers of this equipment will have to contend, since they are matters in which the railroads are most exacting. Maintenance of cars and locomotives already costs the railroads as much as either train wages or locomotive fuel, and any failures in train service add to this expense and the difficulty of operation. The problem is complicated further by the fact that equipment of the type under consideration often could be operated to the best advantage between points that are isolated from shop facilities. While the substitution of a hard and smooth rail would seem to facilitate the adaptation of automotive equipment to rail service, the absence of that element of flexibility afforded by a resilient tire operating over the ordinary highway surface in reality makes the adaptation of automotive equipment to rail service a more difficult problem. Not only do uneven joints and cross-overs introduce more severe vertical shocks, but abrupt changes in the alignment of the rail, as at switches and on curves, cause far more severe lateral shocks than are ever encountered in highway service. Moreover, the absence of any element of elasticity between the engine and the driving-wheel tread, as provided in automobile construction by a resilient tire, operates against the efficiency of the gasoline engine that can be operated only to the best advantage when the transmission is capable of absorbing the ordinary pulsations of the engine and cushioning the shocks occasioned by any abrupt variation in the speed between the engine and the wheel tread.

For these reasons it is believed that the most successful development in this class of equipment will tend toward standards in truck, axle and wheel construction that many years of railroad service have demonstrated as safe and economical; that the use of rotating axles mounted in special journal boxes fitted with frictionless bearings will become general; and that the most desirable form of transmission will prove to be one that is flexible with respect to the vertical and lateral blows transmitted through the driving-wheels. But in whatever development work that is undertaken, either in this direction or with respect to enlarged engine capacity, it is safe to say that the most successful results will be obtained where the experimental work is conducted in conjunction with the railroads.

Finally, in discussing the future of the self-propelled rail-car, the question of greatest importance to the manufacturer and of some moment to the railroads as it may affect the cost of this equipment, is the matter of production which, in turn, depends upon the prospective field for this equipment. It is not unreasonable to assume that in short-line railroad-service, wherever it is possible to dissociate freight-car movement from passenger service, the gasoline-driven rail motor-car will supersede the steam passenger-train eventually. The rate at which this transformation will take place will depend not only upon the finances of the railroad, but upon the attitude of the manufacturer toward financing this purchase. Reliable figures are available to show that wherever cars of this description have been operated by the independent short-lines, they have reduced the cost of operation in comparison with steam service; and wherever the road was incurring a loss with steam service, the gasoline rail motor-car enabled it to make a net profit. Moreover, there are now available several types of car admirably adapted to any class of passenger service ordinarily operated by the short-line railroads.

Trunk-Line Requirements

Turning to the trunk-line railroads, the question cannot be answered as easily; first, because the railroads do not themselves know the extent to which self-propelled rail-cars can be substituted profitably for steam service and, second, because types designed to carry more than 50 passengers at the desired speeds are not yet available.

It is safe to say that there is an immediate field for possibly 1500 cars of the types already available. It is understood, of course, that many railroads will want to delay the purchase of these cars pending the development of new types, while others will want to observe the operation of this equipment on other railroads before committing themselves. Also, the question of financing the purchase of these cars will come up for consideration and it is reasonable to believe that, once a depreciation rate on this type of equipment has been determined reliably, some form of equipment trust applying to a number of these cars would facilitate their purchase. Altogether, the development is yet so new that it may be several years before we can look for any volume of purchases that mean the production of these cars on a large scale, despite the fact that a great field of usefulness awaits them.

THE DISCUSSION

R. B. Abbott[4]:—I am chairman of a committee of the Philadelphia & Reading Railway Co. on the question of the rail motor-car for use on branch lines. After we determine what type is best suited to our purpose, we will then make a study of all cars that approximate this particular type.

A car to suit our purpose must be capable of usage as a motor car with a trailer or, perhaps, another car in addition to the trailer, because the demands on our branches vary so on different days in the week and for different times of the day that a single unit car would not of itself solve many of our problems. The car must also be reasonably comfortable and not noisy or ill-smelling. It should, we think, be capable of control from either end, so that it will not be necessary to turn the equipment at the end of each run.

G. C. Hecker[5]:—When the electric railway people first adopted the light-weight cars, they worked on the theory that they would not replace the seats, seat for seat; that is, they would not attempt to give exactly the same service that had been given previously with large double-truck cars but, rather, increase the service considerably by running cars on closer headway. The people in the different communities found, after they overcame their first dislike for these cars that, perhaps, were not so comfortable as the large double-truck cars, that they were really getting much better service. On a branch line of a steam railroad where very infrequent service is now being given by steam operation, it might be possible, with the gasoline rail-motor-car operating in single-unit light-weight cars, to give a very much improved service. I believe the public can be made to realize that they will get very much better service if they will put up with a little less comfortable car. As the gasoline rail motor-

[4] Assistant general superintendent, Philadelphia & Reading Railway Co., Reading, Pa.

[5] Special engineer, American Electric Railway Association, New York City.

car is developed, there unquestionably will be many refinements that will reduce the objections of the riding public to this form of transportation.

J. E. BURRELL[6]: — The Pennsylvania Railroad has a committee that has been investigating the various types of rail motor-car that are in service at a number of points. The company does not operate any cars of this type on its lines. One car, however, is operated on a branch line by another company. The car is similar to those used by the New York, New Haven & Hartford Railroad, and it has been giving very good satisfaction. We are, of course, somewhat in the same position as the Philadelphia & Reading; we are trying to find the car that will suit our purpose best and, after ascertaining what car that is, we probably will install it on the line.

ARTHUR J. SCAIFE:—It is our understanding that the great need to-day is for some kind of a combination baggage and passenger car that will take the place of the present equipment used on many short-line railroads where it is necessary to use a passenger car, a baggage car and a locomotive, with a full train-crew. This equipment cannot be operated without a loss and the company usually runs one train a day because it is required to do so.

Very little work has been done on rail motor-car equipment by our company, and that has been only within the last few years. We are trying to find out first just what the requirements are with reference to seating capacity. It will be necessary to go at this proposition with an open mind. The thing that we have run up against is that men have been thinking in railroad terms. They immediately criticize a rail motor-car job and ask how it compares with the present railroad equipment and Master Car Builders' standards. If the automotive railcar builders and the railroad operators go at this problem with open minds, I believe that something can be accomplished.

L. G. NILSON:—The present International car, which has a good appearance and is doing very well, naturally has the earmarks of the ordinary motor-truck. I believe that when we consider the larger sizes that the railroads undoubtedly want, we will come back to something like the McKeen car; that is, the power and transmission, the whole drive and equipment should be on the forward truck or at least on one truck. The car body proper could be made very light, with a light trailer, arranged so that it could be uncoupled in a very few moments. In that way the power unit could be gone over at regular intervals once a week, or even inspected once a day, and it would not be necessary to tie up the car body. The car bodies could be run 24 hr. per day or as long as desired.

I believe we will find that a driving unit of this kind equipped with spur gears will give better satisfaction than one equipped with bevel gears. The bevel gears are doing very well in ordinary sizes, but the use of too large sizes causes many difficulties, not so much on account of the gears as on account of the mounting. Unless the mounting and the housings are very rigid, the teeth simply tear themselves out; with spur gears, there is less trouble of that kind.

I would like to predict that we will see an internal-combustion engine almost as elastic as a steam engine in its action, possibly within 3 years. Then the problem of transmission and control will become very much easier.

HENRI G. CHATAIN:—Some 20 years ago, Mr. McKeen induced E. H. Harriman to invest some money in the construction of a rail motor-car that had a mechanical drive. At about the same time I persuaded the General Electric Co. to engage in the construction of gasoline-electric rail motor-cars. Mr. McKeen built some 150 to 200 rail motor-cars and, I believe, they are in successful operation to-day. The General Electric Co. built 100 rail motor-cars and approximately 98 are in operation to-day.

I have listened with great interest to the gentlemen who have spoken in regard to the number of miles that the newer types of car are making. It is interesting to know, and I think the information is correct, that one of our cars recently completed 1,000,000 miles in service, and there are a number of them that have gone over 600,000 miles.

At the time we began to build rail motor-cars, if we had had superintendents on the railroads who would listen to arguments in favor of light weight and not insist upon having many things hitched to the car that belonged to the steam locomotive, we would have built small light cars a number of years ago. But the railroad representatives could not agree with such a viewpoint, and I am not sure that they can agree to-day. Each superintendent wants a different kind of car. Some want trailers; some want to go faster, and others want to go slower. All of this involves differences in design and attendant high cost of production.

Mr. Bean studied the proposition of the light-weight rail motor-car and has convinced me of its merits. He is willing to do without couplers and many other things, provided he gets a good and safe rail motor-car.

I am not an advocate of the mechanical drive. I followed the McKeen rail motor-cars very closely and have the facts and figures covering thousands of miles of their operation and also similar data for the cars built by the General Electric Co., covering a comparable number of miles of operation. The mechanically driven car will operate on less gasoline per mile, but it will cost more for maintenance and repair, because it does not possess what I like to call "squashiness." It is not an automobile with rubber tires, but runs on rails that are not flexible from the transmission viewpoint. No engineer has yet developed ways and means of attaining suitable flexibility between the engine and the track, and this is the important factor so far as the upkeep is concerned.

The gasoline-electric drive has four points of advantage:

(1) The engine can be loaded at all times. As the gas engine is governed by changing its compression, it is obvious that if it can be loaded properly at practically all speeds, and all through its operating range the efficiency can be increased by increasing its average working compression
(2) It is more flexible. The speed changes blend from one to the other because of the nature of the electrical units employed
(3) The prime-mover can be operated at a speed below its normal rate and yet maintain a high car-speed. The high engine-speed is maintained during the accelerating period and for grade work, but is reduced during the period of free running on the level or down a slight grade. These conditions can be well taken care of by the gasoline-electric drive
(4) It makes possible double end-control

I will not take any very decided stand on whether the transmission should be capable of a complete conversion of energy or not. I think that there are a number of transmissions that do not completely convert the energy. They possess all the desirable features such as the flexibility, loading and the various speeds of operation of the

[6] Superintendent of passenger transportation, Pennsylvania System, Eastern region, Philadelphia.

engine, with but small losses of energy. The installation of an engine in a rail motor-car is an extremely difficult thing. It cost us a large sum of money before we found out how to do it. A combination of felt and springs seems to be the most effective; we are using it and it has been reasonably successful.

We built eight-cylinder engines, but they are not as desirable as those of six cylinders or multiples thereof.

The position of the exhaust is an important matter. Mr. Bean points out that there must be some means of preventing gaseous odors in the car, because they are very disagreeable to passengers. We tried every conceivable position for an exhaust and found that the best place to put it is directly overhead, with not too much muffler, so that the gases will go up as high as possible due to their velocity. Exhaust at the rear of the car is prone to roll up and come in through the back windows.

The greatest need in the rail motor-car field to-day, to make it an economic as well as a manufacturing proposition and therefore desirable for both the manufacturer and the user, is the standardization of requirements. This probably can best be brought about by the Society working in conjunction with railroad representatives of authority.

CHARLES O. GUERNSEY:—The gasoline-propelled motor-coach equipment should be only of such size as can be operated with commercially proved engines and handled by a crew of two men. With larger engines that have not been proved out in severe duty and under commercial conditions, we may get into some mechanical difficulty. For cars larger than can be handled by two men, the saving in cost will not be sufficient as compared to steam equipment to justify the use of gasoline-propelled cars. Like any other broad statement, this is undoubtedly subject to some limitation.

Generally speaking, the gasoline engine above about 5-in. cylinder-bore has not been proved in commercial automotive service. It is true that large engines have been used in various installations, such as aircraft or private yachts, but for such service the first cost, operating cost and maintenance are not of prime importance. Engines of this type would not be satisfactory in motor-coach service. If we assume then a 5-in. cylinder as being the maximum that can be used safely, we are confronted immediately with a limitation of horsepower dependent upon the number of cylinders that are used. Four-cylinder engines of this size have been well proved and undoubtedly will be successful in this service. It is possible that some six-cylinder designs which are now on the market may also be successful. For larger powers, nothing has been developed as yet, and I doubt whether there will be a sufficient demand to justify the development of 8 or 12-cylinder engines for this service, to say nothing of the complications incident to such a multi-cylinder design. If the foregoing assumptions are correct, we are limited in the case of a four-cylinder engine to about 70 hp. as the maximum that is available; or, in case we accept the six-cylinder design of about the same cylinder bore, we can expect to get about 100 hp.

The designer of these cars should bear in mind that the car must represent a combination of automotive and railroad practice. The railroad standards as to safety, comfort, steadiness of riding and low cost of maintenance and operation must obtain. Because of the limited power available, the weight must be kept to a minimum. This indicates, therefore, the use of alloy-steels, light-weight designs, anti-friction bearings and the like, as customarily used in automotive practice and as already proved in such service. The weight of car that can be handled satisfactorily with the engines of the powers mentioned will depend, of course, upon the speed required, the road conditions, the number of stops and the acceleration that must be had.

In general, it is my opinion that, with the four-cylinder engine, the outside limit of weight for general all-around satisfactory performance is about 18 tons loaded, and for the six-cylinder engine the outside weight should not exceed from 22 to 25 tons. In a properly designed car the four-cylinder engine should handle about 45 passengers in combination with a baggage or express load of about 1 ton satisfactorily. The six-cylinder engine probably would handle a passenger load of from 55 to 60 passengers in combination with about 2 or 3 tons of baggage.

Demonstrations of a four-cylinder railroad motor-coach developing 61 hp. show the results given in Table 2.

TABLE 2—ACCELERATION OF A FOUR-CYLINDER RAILROAD MOTOR-COACH[7]

Acceleration from a Standing Start to Speed, M.P.H.	Time Min.	Time Sec.
25	..	30
29	1	..
35	2	..
41	2	40

[7]Light weight of car, 13 tons; loaded weight, 17 tons.

The gasoline consumption varies from 5.2 to 7 miles per gal., depending upon the conditions. The normal speed of the coach at the rated speed of the engine is 35 m.p.h. and the maximum speed with full load is 48 m.p.h. The operating cost, including a crew of two men at standard wages, gasoline, oil, maintenance, depreciation and interest on the investment, is about 29 cents per mile. This figure will, of course, vary with the local conditions.

W. G. BESLER[8]:—In my opinion, there are certain places where a gasoline-propelled vehicle finds its proper application in railroad service, but in those cases where a cement highway costing from $40,000 to as high as $120,000 and in some cases even more per mile, is constructed at public expense, paralleling a railroad, why should branch-line service, which is the only place where a gasoline rail-car finds its proper use, he continued? In such an instance the railroad company had better stop operations, invest its money in motorbuses and continue service upon a highway provided for it free of expense, than subject itself to the burdens of expense for rails, which require renewal, maintenance, supervision and all that goes with railroad service.

GEORGE L. SHINN[9]:—Our designation of the practical application of the gasoline-driven rail-car at present is that it can be used with great advantage for light traffic conditions. I say this because on our road we have substituted a White combination passenger-and-baggage car where we formerly used a steam locomotive and two passenger coaches to handle the traffic. We have not yet arrived at a definite figure but a conservative estimate indicates that, by the use of this gasoline-driven car, we will effect a saving of $15,000 per year. We believe that, by the use of this gasoline-driven rail-car, we are giving service superior to that formerly rendered, and we note from the expressions of opinion that have reached us that the patrons on the line are much better satisfied. We maintain the same schedule as when the steam trains

[8] President, The Central Railroad Co. of New Jersey, New York City.

[9] President, Pennsylvania & Atlantic Railroad, New Egypt, N. J.

were in operation and find that we could give even greater service should it be necessary and desirable.

The car that we have in operation is governed for a maximum speed of 33 m.p.h. and, due to its excellent acceleration and easy handling, we are maintaining the former steam-train schedule without difficulty and could, if desired, stiffen this schedule. We have no hesitancy in saying that our experience with the gasoline-driven rail-car is very satisfactory in every way.

J. W. CAIN[10]:—In making our investigation of gasoline-propelled rail motor-cars for the member lines of the American Short Line Railroad Association, we did not go into the subject technically but, instead, considered the different cars more from the standpoint of practicability as evidenced by actual service. We approached the subject from three different angles and our final conclusion was based on a summation of the information thus received.

Our membership consists of some 500 different railroads located throughout the United States, and for a great many years they have been the proving grounds for the different rail motor-cars brought forth. Indeed, there has seldom been a gasoline-propelled railroad-car built that has not at some time or other found its way to one of these properties. We, therefore, had a source of extremely valuable information and sent to each of these lines a questionnaire, of which the following are the principal questions:

(1) Are you using motor equipment on your line, and if so what make?
(2) How long has it been in service?
(3) What is your average operating cost per train mile?
(4) Approximately what mileage do you get per gallon of gasoline?
(5) Do you experience any trouble from slippage in rainy or snowy weather?
(6) Have you had any serious trouble from derailments on curves?
(7) Of the different commercial designs now on the market, which do you consider the most satisfactory?
(8) Do you expect to be in the market for rail motor-car equipment in the near future and, if so, what equipment will you need?
(9) Give us your suggestions as to the necessary compartments and toilets as suggested by the demands of your service or required by your State Railroad Commission

There was a most gratifying response, indicating great interest in the subject, and from these answers we were able to arrive at certain definite conclusions.

We have a used-equipment department in the Association, which is a sort of clearing-house among our member lines as well as some of the trunk lines, and from this we secured a tabulated list of all the rail motor-cars offered for sale. This threw a most interesting spot-light on the entire subject.

We made a personal inspection of the most successful cars available and spent a great amount of time in making demonstrations and in looking over the manufacturing facilities of the firms proposing to build them. There were some cars offered that we did not examine because we considered them impractical or not soundly financed.

Summing up these three phases of our investigation, we found that the most successful cars in service were those of light design, using a thoroughly tried and proved make of motor-truck power-unit or chassis. One make in particular showed a preponderance over all others in the ratio of probably 5 to 1. We were furnished records of cars that had made as high as 300,000 miles, and been in practically continuous service for a period of 5 years. The operating cost varied from 10 to 25 cents per mile, and the gasoline consumption from 5 to 10 miles per gal.

We found the maintenance cost surprisingly low, averaging about $15 per month on these smaller-type cars and only slightly above this on the larger ones. By smaller type I mean those using a 2½ or 3-ton motor-truck chassis, and by larger cars those using 5-ton chassis. The operating cost of 10 cents per car-mile was, of course, confined to the former, which were being operated by one man. But some of the larger types using two men were being operated as low as 20 cents per car mile, as given in Table 3.

The figures in Table 3 were made on a basis of $12,500, the purchase price of the car, and an operation of 100 miles per day.

TABLE 3—COST OF RAIL MOTOR-CAR OPERATION

	Cost per Mile
Gasoline	$0.030
Labor, two men at $125 per month	0.085
Depreciation, rate 12½ per cent	0.042
Interest and Insurance	0.022
Maintenance	0.021
	$0.200

It was revealed that the majority of cars on the short lines were being operated most successfully by younger men, who were trained as mechanics and who were thus able to take care of practically all of the necessary light repairs. I think this point should be emphasized strongly, as the labor cost is one of the principal single items in the operation of rail motor-cars, and the payment of standard wages would defeat the object to be accomplished. At least this is true on the short lines. We take the position that the operation of these cars does not require the skill or training necessary to operate a steam locomotive. They have never been classified by the Interstate Commerce Commission, and I feel sure that our position would be upheld.

The consensus of opinion was that all cars should be equipped with a pivotal lead truck for safety and that a single pair of drivers with the proper weight distribution gave satisfactory service, though the riding qualities of the car were naturally not as good as though a four-wheel truck with swing bolster were employed.

The different rail motor-cars offered through our clearing-house revealed that practically every road owning the old heavy and now obsolete types, some of which are not now being built, desired to sell them at prices ranging from $500 up. Of all of the cars offered, however, there was not a single one of the modern light adapted truck type.

In our personal examination and inspection of the different cars offered, we found that the light six-wheel type cars up to a length of 36 ft. and a weight of about 20,000 lb. could be operated successfully at a speed of from 30 to 35 m.p.h., making from 5 to 6 miles per gal. of gasoline. Beyond this, there is too much vibration, and the single-driving-wheel arrangement makes the car ride uncomfortably; but for a capacity up to 35 passengers and about 2000 lb. of baggage, we found this the most successful car of the present time. Above this capacity, we examined a car 43 ft. in length, equipped with two four-wheel

[10] Manager of purchases, American Short Line Railroad Association, City of Washington.

pivotal trucks that was capable of making a maximum speed of slightly better than 40 m.p.h., at which speed it rode very comfortably. The weight of this car was about 30,000 lb.

In conclusion, I believe that these cars will prove the salvation of many short-line railroads, as well as the branch lines of the larger systems; and, as a large number of our member lines have stated, they have changed their figures from red to black. While the cars that we have been discussing are absolutely successful and will faithfully perform the duties imposed on them, I feel that efforts should be expended toward the development of a higher-powered engine, as the present ones have none to much power. I do not mean to increase the bore of the cylinders or go to the slow-speed marine-type of engine; but, instead, to increase the number of cylinders and adhere strictly to the successful and proved type of automobile engine.

HOT-SPOT METHOD OF HEAVY-FUEL PREPARATION

(*Concluded from p. 476*)

lutely preventing crankcase and cylinder-wall lubricant-dilution.

Successful application of the separating hot-spot demands only an ordinary knowledge of the laws of physics relating to heat, and presents much less difficulty than a number of other problems that our automotive engineers have solved. It is only a question of getting an adequate heat-supply from the exhaust and of excluding heat communication from other sources. As suggested in the foregoing, the entrance-air temperature should be the lowest that can be obtained, and care should be taken to avoid conduction of heat to the intake system beyond the hot-spot. In particular, careful attention must be given to the heat insulation between the heating surface and the remainder of the enclosing walls of the intake system, as a tremendous amount of heat can be conducted across the ordinary flange-joint.

Our experience indicates that the separating hot-spot should always be located in the main exhaust line and that it is hopeless to attempt to pipe the exhaust across a T-head engine, or the like, as the temperature drop will result in too low an exhaust temperature at the lower speeds. Also, the actual flow of exhaust to the hot-spot will be a function of the muffler back-pressure, which will result in exaggerated temperatures of the mixture at high car-speeds.

DURALUMIN

(*Concluded from p. 480*)

and length to do more than describe the physical and metallurgical properties of duralumin and touch on some of the applications of interest to the Society. However, the automobile engineer should realize that now he can avail himself commercially of this extraordinarily light yet strong material as the aeronautical engineer has done. The development of the Zeppelin was dependent upon the development of duralumin, and the rapid progress of the all-metal airplanes since the war has been due largely to the commercial availability of the same metal. While the automobile is not as dependent as the airship or airplane upon a material of this class, nevertheless modern automobile design tends toward the elimination of unnecessary weight. The extensive introduction of duralumin into automobile construction, especially in unsprung and reciprocating parts, will permit of a complete redesign, effecting economies that will offset its greater cost as compared with steel. Such a car will bring nearer the ideal combination of road performance and economy of upkeep and operation.

Oil Consumption

By A. A. Bull[1]

Semi-Annual Meeting and Detroit Section Paper

THE subject of oil consumption was discussed at the meeting of the Detroit Section held Sept. 29, 1922, following the presentation of the paper bearing this title that was prepared by A. A. Bull for the 1922 Semi-Annual Meeting of the Society. An abstract of Mr. Bull's paper precedes the discussion. Members who desire to refer to the complete text as originally printed and the illustrations that appeared in connection therewith will find these in the June 1922 issue of The Journal.

ABSTRACT

THE object of the paper is to consider some of the fundamental factors that affect oil consumption; it does not dwell upon the differences between lubricating systems. Beyond the fact that different oils apparently affect the oil consumption and that there is a definite relation between viscosity and oil consumption, the effect of the physical characteristics, or the quality of the oil, does not receive particular attention.

The methods of testing are described and the subject is divided into (*a*) the controlling influence of the pistons, rings and cylinders; (*b*) the controlling influence of the source from which the oil is delivered to the cylinder wall. The subject is treated under headings that include the piston-ring; the effects of oil-return holes, side-clearance and ring motion; thin rings; influence of piston fit; efficiency of the scraper-ring; ring and cylinder contact; carbonization and spark-plug fouling; oil-supply control; influence of oil viscosity; effects of dilution; external oil-leaks and breather discharge; and influence of controlling lubrication in proportion to throttle opening.

THE DISCUSSION

A. L. Clayden:—I have devoted much thought to scraper-ring action, because there seems to be so much difference of opinion about it. It appears possible to me that in some cases it would work effectively and in others be actually detrimental. The ring mentioned is arranged at the bottom of the skirt so that it runs half out of the bore. It is useless unless it does run half-out, because there is no space for the oil it drives before it to escape. I wish to emphasize that on the down-stroke of the piston the scraping action of the lower one of the several compression rings builds up a very high pressure in the oil-film that is being scraped before it; so, even if the cylinder film is not any too complete, that scraping is enough to insure that the space behind the ring will be completely filled with oil. The depth of the space behind the ring is probably not a very important function, with the amount that is pumped, because if you regard the piston-ring as a pump piston or as a valve, it will only pass the quadrant, or 90-deg. position, of its stroke. But one can be sure it will be fed full, all it can take; hence the extreme value of the relief holes or grooves immediately beneath the ring and the great value of the ring with sidewise expansion; by "sidewise" I mean fitting the groove expansion.

The crank drilling that Mr. Bull mentioned is probably one of the most important things to study. To some slight extent, a study of the development of various aviation engines was made. It was found to have a very profound effect upon the oil consumption and on the lubrication of all parts of the engine. In fact, all kinds of changes could be made by simply moving the hole around the pin. In many of certain new engines, we finally hit upon a 90-deg. position as giving the desired results; but, of course, a very considerable quantity of oil must circulate for the purpose of cooling.

O. C. Funderburk:—I was connected with the designs of some marine engines ranging in cylinder size from 6¼ to 7¾ in. and developing from 300 to 450 hp. In the multiple-bearing crankshaft we used, it was necessary on account of the high powers to carry oil pressures in each individual crank control. That is, we would have to cut-off the communication all of the way through the shaft, as is apparent in the Liberty engines because of this long crank-arm. We run this 7¼ by 9-in. engine at 1650 r.p.m. The centrifugal force and the load constitute very large factors in the distribution of the oil, and cause over-oiling in the particular cylinder that has the loosest journal and crankpin bearing. We found it necessary to put a plug in the main-bearing journal of the crankshaft and to make individual crankpins for each cylinder. That greatly decreased the over-oiling in any cylinder where there were loose bearings in proportion to the adjacent cylinder. We found also, as Mr. Bull did, the necessity for moving the oil-hole from the outer position on the crankpin to an inward position. The position we use is 10 deg. from the underneath position. That, we found, made a great difference in the distribution of oil. We also found a great change in consumption due to pressure. We have experimented with pressures of from 10 to 250 lb. per sq. in. We found that a pressure of about 30 lb. per sq. in. gives the highest horsepower with the best oil-consumption. The excess power required to drive the pumps at the exceedingly high pressure and the cooling of the oil absorb sufficient power to note the difference on the dynamometer. We obtained the best oil-consumption in our engines when the oil had a temperature of about 108 deg. fahr. The temperature sometimes ranged from 100 to 120 deg. fahr. with Mobil-Oil B, and Veedol extra-heavy. The temperature of the oil ran as high as 150 deg. fahr. and there was a marked increase in the consumption. If the oil was colder than 80 deg. fahr., we found an excessive amount of oil on the spark-plugs. This proved very conclusively Mr. Bull's statement that the film of oil on the piston, if three rings on the top and one scraper ring are used, could not be discharged on the ring, and the unit pressure between those upper and lower rings would discharge it on the piston. As soon as we got temperatures of the oil as low as 50 deg. fahr. the fouling of the spark-plugs with over-oiling became very much more apparent.

T. J. Litle, Jr.:—I am not a believer in the velvet, or rough, finish on the cylinder bore that some companies have practised, and the rough rings. At least one engine company in this Country has practised finishing the bore, grinding it four times and honing the surface. The final honing operation is done with a stone of very fine grade, leaving the cylinder wall in a polished condition. Many of us have looked into engines after they have been driven several thousand miles and greatly admired the boring. That is the way it should be done at first, and

[1] M.S.A.E.—Chief engineer, Northway Motor & Mfg. Co., Detroit.

the pistons and rings should not be used as laps to do it.

A thick piston-head is necessary if a cast-iron piston is to operate very satisfactorily in a passenger car. Unless a thin-headed piston is used, the piston is heavy and the engine vibrates excessively. Therefore, I do not believe in using cast-iron pistons.

There has been a very great development in aluminum pistons recently in this Country. I refer to the aluminum-alloy pistons containing about 10 per cent copper, and heat-treated to increase the hardness from 75 to 80 up to 175, almost as hard as cast iron. That has an indirect bearing on this whole problem, because when a light piston of great hardness is produced, the ring grooves will not wear. It is when the ring grooves wear that the engine starts to pump oil excessively.

We all know that, if the depth of the ring is increased, its life is increased, for it will not wear the groove wide so quickly. Many companies are careless in fitting the ring in the groove. Some rings are tight and some are loose at the start, right from the factory. The inertia of the ring hammers the groove wide, particularly where the former does not fit tight.

The construction of the ring itself affects oil consumption most. A plain one-piece ring that has a real scraping-edge on the bottom will control the oil-flow. I do not mean the conventional 90-deg. corner, but that if the ring is cut in at an angle and a scraping edge is established at the lower side of the ring, the oil consumption will be changed wonderfully. On a given engine that is consuming oil at the rate of 1 gal. per 300 to 400 miles, the oil consumption can be decreased to 1 gal. per 2000 miles by simply modifying or sharpening the scraping edge of the bottom of all of the rings. The scraper ring does the most good when a line is cut under the edge of the piston. In other words, if the piston is right up to size, if the liner under the piston ring, the lower ring, is the same size as the rest of the skirt, it does little good. But if that point is cut under, its efficiency is increased greatly.

If a little gash is cut in the lower part of the ring at rather an acute angle the scraping effect is very marked. It is just like that of the ring itself, and it does not provide any oil-holes in through the cylinder or employ these in every ring. We experimented on the dynamometer about a month to determine this angle. We varied it every 5 deg. and the difference in the scraping effect was remarkable. With an acute angle I think there is a certain flexing of the edge. In other words, it acts like a chisel going down an oil-stone; you can scrape all of the oil ahead of it, and leave the oil-stone dry. But if a plain piece of metal with a square edge is put down there, it will leave a film of oil.

CHAIRMAN GEORGE E. GODDARD:—I think that the great advantage of that angle feature is that it provides an edge which sharpens itself.

MR. LITLE:—I believe that the greatest scraping, of course, is on the lower ring below which there is a gash right through to the interior, but no small holes. We had difficulty in getting enough oil through the holes. It is an expensive operation to cut a little slot around the skirt and drill a number of little holes in it. A gash cut right through is, I think, the best construction. It is used very largely on the aluminum-alloy piston and is very effective.

MR. FUNDERBURK:—In connection with the discharge of oil from the rings through the holes, we have had the experience Mr. Litle relates. We started with 12 No. 40 drilled holes below the scraper hole. That was the third ring from the top. We have increased the size of those holes, and finally we have now 22 holes of 3/16-in. diameter, which, of course, is greatly in excess of the area of the annulus represented by the clearance between the cylinder and the piston.

In a design we prepared for the Government we inaugurated some experiments in which we ran the shaft on the same bearing pressure as when the engine was on full power. We found it necessary in connection with the oil pressure to use a refrigerating system to cool the oil, so that we could lubricate at very high speed without scoring; the bearing is 5¼ in. in diameter and runs at 1400 r.p.m., which is far above anything in my experience which had been undertaken in our line before.

J. E. WHITE:—We find in many cases that, if some of the so-called heavy oils are used, the engine cannot be cranked at more than 30 to 40 r.p.m. If an oil that has the proper base is used in winter, one can get as high as 50 or 60 r.p.m. I am speaking of the Packard, the Lincoln, the Cadillac and the Lafayette types of engine.

L. M. WOOLSON:—So far as the minimizing of oil consumption goes, we have found that we can get practically anything we want. We can get an engine to run 5000 miles per gal. of oil if we so desire, or we can do even better than that. But the fact of the matter is that an allowance must be made for sufficient oil-consumption so that the average owner will maintain his oil supply. We have had owners proudly boast about running 10,000 miles and not using a drop of oil. To avoid that condition, we have fixed our engines so that they will use some oil. That is the only possible way of getting fresh oil. We must have fresh oil until we get this dilution problem solved. I think that none of us is really working on this dilution problem as seriously as it deserves. There are two general ways of keeping the oil consumption down, but I think we cannot use either of them until we get the dilution problem solved because a job that will run 5000 to 6000 miles per gal. of oil in the course of the use of a car by the average owner, will be ruined in fairly short order, especially in the cold winter months.

To my mind there are two ways in which we can really control the oil consumption best; by baffles and by scraper-ring construction. We used a scraper-ring construction on high-compression engines with very great success. If we go too low with the oil-consumption we find we get into trouble from hot pistons and hot exhaust-valves. In high-compression aviation-engines some oil must be passed into the combustion-chamber to keep the exhaust-valves cool.

The ordinary type of baffle consists of a slotted plate fitting the cylinder bottom, the rod working through the slot. A baffle like that is worse than useless, because of the high velocity of air going by the slot which results in carrying a great quantity of oil with it, and the result is that instead of decreasing the oil supply it is generally increased. If the baffles are arranged in the form of semi-circular guards that have the crankshaft center as their center and these guards are extended over the ends of the connecting-rod bearing, the oil can be practically prevented from reaching the cylinder. I do not know why that is not a very much better way than trying to get extremely accurate fits between the piston-rings and the cylinder and the ring grooves, which cannot possibly be maintained during thousands and thousands of miles of travel.

We have been taught for many years that the place to feed the oil is on the slack side of the bearing; yet Mr. Bull tells us that the place to feed it is on the tight side or, in other words, so that the bearing will plug up the hole. I have had some intensely practical experience

with just that construction which enables me to make such a positive statement that, from a bearing standpoint, it is positively the worst thing one can do.

We had a 600-hp. aviation engine on a 50-hr. test. At the end of 25 hr. we found the bearings in pretty bad shape. We then went through this same analysis of bearing pressure that has been discussed and found just what Mr. Bull found. Therefore, we decided to put the hole just where he said we must not put it, on the slack side, so that we would surely get plenty of oil there. We ran that engine another 25 hr. with new bearings and the new oil-hole location but everything else the same, and those bearings stood up. Since that time we have always located the oil-feed holes on all our jobs at 45 deg. leading, which represents the zone of least pressure. That gives us an ample flow of oil through the bearing, and helps to dissipate the heat. You can trap the dirt just as well by pressing a tube in the oil-hole as long as desired.

F. E. WATTS:—I think that the principal value of Mr. Bull's paper is possibly not in the conclusions he reaches so much as in the method he follows. I believe it is the method that must be followed in working out the oil problem in any engine. He starts with the oil coming up to a point where it can possibly be drained without giving any trouble. Then he follows that oil through all of the various passages and the places it can go to get into the cylinder. I believe that is the way we must lay out any engine. Lay it out on paper and theorize upon it. Possibly, make models and study them as much as you study the engine because, if the engine once gets to running at high speed, so many things happen in it that the different things cannot be segregated.

I believe that the ideal oil-consumption at present is about 1 gal. per 1000 miles. Keeping between that figure and 1 gal. per 400 to 500 miles is doing pretty well. Using large quantities of oil keeps the grit out of the cylinders and the bearings, and the engines last enough longer so; that pays more than the oil costs. It is perfectly easy to study the combustion-chamber and locate some point in it where the spark-plug will keep reasonably clean even if there is a quantity of oil coming onto it.

CHAIRMAN GODDARD:—In some of our experiments for reducing oil consumption we got so low on the oil that we began to get spark knocking. We found that the amount of oil had been cut down so that the carbon deposit we get from the poor gasoline was not moistened. I think that with filtered gasoline we get better results than we do, even to-day, with hot-spots and the like. Our experience is that there must be a little bit of oil in the combustion-chamber to keep the top of the piston moist.

H. S. McDEWELL:—As some of you may know, in the Navy Liberty engine a scraper with holes is provided. The oil consumption was reduced as a result of that. The 1700-r.p.m. consumption was cut from 14 to between 5 and 7 lb. per hr. In starting that work we went through a rather laborious research to determine what shape that scraper ring should have, and as to whether this feathered ring was sufficiently better to warrant the increased cost of production. Therefore, we devised a hot plate and a block of 1-sq. in. section. One edge was right-angled, another edge was at 16 deg. and the third edge at 30 deg. We provided a load such that the pressure would be 8 lb. per sq. in., which is the rate of pressure on the piston-rings. We then measured the thickness of the oil-film, and scraped this slot across the plate, which was maintained at a temperature that we assumed to be practically that of the oil-film. We found that under the same unit-pressure, while there was a difference in favor of the sharp edge, it was not sufficient to pay for the increased cost of producing such a ring. Consequently, we adopted the small square ring; and it provided ample space into which to scrape the oil and ample drain-holes. The size of the hole we used was 3/16-in. in diameter. We used 14 of them. I think the cause of the failure of holes of very small diameter is the high surface-tension of the oil, so that an oil-film bridges across those holes and offers too much resistance to the flow of oil draining out to the other side of the piston.

Particularly in the aluminum-alloy piston with cast-iron rings the thing that must be guarded against is not so much the initial clearance as the differential clearance; that is, the increase in the clearance that is due to the different ratios of expansion, the coefficients of expansion of the groove and the ring. The narrower the ring is, the less the actual change in the clearance will be. Consequently, very much better results are obtained with the narrower rings.

In regard to the location of the scraper ring at the bottom of the skirt, it has always seemed to me that this would be very analogous, in the case of steam-engine practice, to installing some device to prevent lubrication of the crosshead. The piston, or the skirt portion of the piston, is the crosshead in the gas engine and it should be lubricated. The same thing applies to the use of baffles to prevent the throwing of oil up from the crankshaft. The real solution is to prevent the oil from working past the piston-rings, and to provide ample lubrication for the crosshead surface itself.

MR. LITLE:—Placing the feather edge in the bottom of the ring requires 14 sec. for the actual operation. I would rather determine its value by actually knowing how long and how well it produces on the job than in a laboratory machine such as Mr. McDewell used for that purpose.

I agree that the piston and the edge of the crosshead should be oiled copiously. I think it is not advisable to place guards around the bearings to prevent the oil from splashing up into the cylinder bore. It should be just slathered with oil. There should be plenty of oil for the cylinder and plenty of oil to pass to the skirt of the piston. The rings should be used to control passage of the oil.

My experience with engines that use 1 gal. of oil every 300 to 400 miles is that they are using too much oil. It requires too frequent visits to the service-station to have the carbon cleaned out.

CHAIRMAN GODDARD:—We were ready to put in baffle-plates but found that in using the aluminum piston with the large slot we kept the oil down enough so that we did not need them. Also, we are driving away more cars than ever before due to the railroad congestion and it would not be well to keep cylinder lubrication down in these new cars that many times are abused by irresponsible drivers.

We have, however, provided a place in the cylinder where baffles can be added after 5000, 10,000 and 15,000 miles, to keep the oil consumption down if this becomes necessary. By using a volume of oil, the oil lasts longer, and it will stay in better condition. Some of those here have spoken about the rings with the scraper groove in them being in the bottom groove of the piston. I assume that they mean the lowest groove above the wrist-pin. Our experience has been that, if they are put there, not enough oil gets above them to lubricate the two upper rings satisfactorily. Our practice in using scraper rings has been to put them in the top groove, but we could not always get enough drain-holes in there.

A. A. BULL:—It is unfortunate that in considering this question of oil consumption we are usually inclined to pick out some particular feature, instead of trying to consider the matter as a whole. Consequently, as has been evident, in almost every instance, changes or modifications may, under some conditions, prove absolutely ineffective under others.

The thing that counts is what happens in service. The purpose in locating the oil-discharge hole as I recommend is to get a condition that will exist throughout the life of the engine regardless of the bearing clearance. In other words, there is a certain discharge from the crank when the engine is new, and it is desirable if possible to keep that quantity of discharge the same regardless of the bearing fit. It is inevitable that the bearing will get loose. If you have an excessive bearing-clearance there is absolutely no guarantee that the oil will reach the place where the bearing pressure exists for the greater part of the time.

So far as providing adequate lubrication is concerned, the time that you get the discharge is when you change the direction of the pressure on the crankpin due to the influence of the pressure in the cylinder; the greater the load is, the greater the interval will be; consequently, the greater is the supply of oil. Mr. Woolson said that it was shown that the bearings on some engines do not stand up as well. I maintain that was not because there was not sufficient lubrication or that the oil was not sufficiently distributed, but rather that the temperature reached under these particular operating conditions required a larger portion of oil to be circulated. That may be because the clearance was inadequate. We must recognize that high temperatures call for a different clearance.

We must have a definite amount of lubrication in the cylinders. I grant that absolutely. But again I say that if, when the engine is first built, the lubrication given the cylinder is a definite amount, and if we agree that is sufficient, all we want to do is to maintain it. In placing the oil-hole at the top of the pin there is no question that the discharge from the cylinder increases as the bearing wears. If, in order to control the oil going into the cylinder, baffle-plates are placed over the bearings, the effect of which is to do just what we are trying to do with the oil-hole location, I would like to know how we expect, when the engine is new, to get any oil in there at all. Under conditions where the job is new, we should have the most oil; and, after the engine is worn, we need the least. With the ordinary construction and oil-hole location, we take steps to give it more when it needs less.

On the question of how much oil we should use, I believe that 1 gal. per 1000 miles is good all of the time.

On the question of ring wear and piston hardness, I am a champion of the aluminum piston. Mr. Litle believes that we will eliminate the troubles with an aluminum piston in regard to the side clearance of the ring when we make the piston as hard as cast iron. My arguments on this are that, while we may do things to the piston and rings that will more or less limit the wear, sooner or later it will occur. What I would like to do, if possible, is to provide something that will take-up wear automatically and maintain the condition that we know should exist.

We argue that making the ring thinner will reduce the force of inertia that is responsible for the wearing down of the grooves. If that is the predominating cause, why is it that the top ring in the piston, and the second ring, will invariably wear at a considerably greater rate than the rings below it? I have seen instances where, after both top rings were worn as much as 1/32 in., the third ring was in fair condition and the bottom ring in the same piston and subject to the same inertia process practically in the same condition as when originally installed. I think that there are some other factors affecting this wear that we do not appreciate fully.

As to properly finished cylinder bores, I used to argue that it is useless to put on a very fine finish and make a nice round cylinder bore, because I did not know just what the shape of the cylinder would be under operating conditions. Subsequently, in the development of pistons, we found that the cylinder was a peculiar shaped one under operating conditions. Afterward, we made an engine with cylindrical sleeves the same thickness all of the way around and machined both inside and out. Then we found that whatever we put in the cylinder to start with was maintained pretty well under operating conditions. Rings and pistons that would not produce a compression in the ordinary cylinder, no matter how well it was finished, would work perfectly well in the inserted-sleeve type of cylinder bore because, under the conditions in which the engines were operating, we had a fairly constant relation between the ring and the cylinder.

In an experiment we made 4 or 5 years ago, we drilled a number of holes in a piston immediately below one ring-groove. We put in the ring with just an ordinary mechanical fit, cleaned the piston on the inside and painted it white, so that we could trace the flow of oil through the holes. We made a partition on the bottom to prevent any oil from being splashed inside. We ran this piston in the cylinder until there was evidence of oil passing up to the top surface of the piston. We expected, of course, to find that the oil had been scraped off the cylinder wall by the ring and pushed through these holes, but the oil was not there. It did not push through until we made the ring a real tight fit in the groove. When you make a large hole or slot such as you have with the slipper type of piston, it makes it that much easier for oil to pass through. Probably it will be more effective than the ordinary 1/8 or 1/32-in. holes would be under the same running conditions.

I made a fairly definite statement in my paper to the effect that I do not believe piston clearance of itself has anything to do with oil-pumping. I think that the fit of the piston in the cylinder does have an effect on the way the ring functions. In that respect I agree that the location of the piston-pin has considerable to do with that because, if you have 0.006-in. clearance and the piston-pin is located near the top of the piston, the angle of the piston in the cylinder will be much greater than if that same piston were provided with a pin in the middle of its bearing face. There is a too prevalent opinion that this question of clearance is the real cause for oil-pumping. Let us consider for a moment the sloppy type of piston. It is exposed completely on two sides. The oil-film would come up 1/2 in. thick if it could, but it cannot. If it be true that clearance in itself will permit a larger quantity of the oil to cling to the walls, then I would say that the slipper type of piston would be a very poor job from the standpoint of oil-pumping. Yet it has proved to be very good and for no other reason, in my opinion, than that it is much easier with a large clearance actually to displace the oil-film or roll it up off the cylinder bore and push it through the holes.

The character of the lower edge of the ring is important. I made a statement to that effect in my paper,

(*Concluded on p.* 519)

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The Modern Airplane and All-Metal Construction

By WILLIAM B. STOUT[1]

METROPOLITAN SECTION PAPER *Illustrated with* PHOTOGRAPHS AND DRAWINGS

THE author emphasizes that the best type of airplane combines in its make-up a complete solution of structural problems with the best aerodynamic compromise, and that the eventual airplane will expose no parts to the air that do not give back a resultant lift for their resistance.

After outlining the structural problems, the progress of the development of thick-wing and all-metal airplanes with which the author has been identified is reviewed and illustrated. Thick-wing problems are discussed and the requirements of all-metal airplane-construction are stated. The author believes that future commercial airplanes will have all-metal construction.

A DISCUSSION of the airplane of to-day when the new industry is progressing so fast must, of necessity, include planes now being built and in the course of laboratory development as well as those actually in use. Just what the modern airplane really is, as to detailed description, depends largely upon which particular engineer describes it; each one will state what his research shows, in his judgment, to be that combination of structure and aerodynamics which constitutes the best airplane. Again, the best airplane for some specified usage may be the worst airplane for some other specific purpose.

In comparison with the marine field, the aerial speed scout of to-day is represented by the racing hydroplane or speed boat, which, with a tremendous amount of power per pound of vehicle, still carries but very little load and sacrifices everything to speed. This speed type of airplane is by no means a commercial type, and I believe it is the commercial type in which the Society is interested primarily at present.

Directly opposite in the comparison is the old type-B Wright biplane which, with a 30-hp. engine, flew at slow speed and carried a weight of about 50 lb. per hp. This, in aerial parlance, compares in a way with the rowboat that has a motor attachment which, with a very small amount of horsepower, carries a heavy load per horsepower but travels at very moderate speed.

The attempts of designers to-day are largely toward reducing the amount of horsepower required for flying by two methods; (*a*) by reducing the amount of dead weight carried for a given useful load and (*b*) by seeking a minimum of "parasite" resistance toward forward movement, as against useful resistance which gives back a resultant lift.

As I have pointed out to the Society before, there are two major branches of airplane design; the first is structural, and the second is aerodynamic. An airplane comprising poor aerodynamics and very light successful structure will fly, but one of perfect aerodynamics with faulty structure is of no value whatever. The structural division of research, therefore, absolutely must be solved, and *that development is the best airplane which combines in its make-up a complete solution of structural problems with the best aerodynamic compromise.*

In the past, too many designers have approached the airplane from the standpoint of wing curve, lift-drift ratio and the like; forgetting that, after all, he who can build the lightest areas for a given strength has produced at least the fundamentals of the best airplane. Airplane design to-day, therefore, is largely a structural problem.

STRUCTURAL PROBLEMS

The structural problems that arise are subdivided into the necessary materials, and the arrangement of those materials. The original Wright efforts were biplanes made of spruce, cotton shirting, piano wire, stove bolts, tire tape and the like. The original Bleriot design, using almost the same materials, was of monoplane arrangement with a different type of landing gear. From that day, until recently, the airplane designer added but little either to the arrangement of the structure or the materials used. Our DeHaviland war airplanes were built of the same spruce and ash and cotton cloth, but saved a few pounds of weight on the airplane by the use of expensive nickel-steel bolts instead of stove bolts costing but a few cents each. The details of airplane construction have improved wonderfully, but the materials and the arrangement of the structures developed but little for a long time.

It must be admitted that the present-day airplane, as now in use, carrying about 28 to 30 per cent of useful load and a pay load of 3 to 5 lb. per hp., cannot hope to be the eventual commercial-passenger or freight-carrying machine. Ways must be found, if a real commercial airplane is to be available for air lines, for improving the structural part of the present type of airplane to make it lighter and stronger and cheaper. This can be done by using better materials and providing better structural arrangement, and then combining with them improvements in aerodynamics. Aerodynamic improvements include better wing curves and the elimination of parasite resistances by better arrangement of the design and better streamlining of those parts that must be exposed.

The eventual airplane will expose no parts to the air that do not give back lift in return for their resistance. This airplane will be practically nothing but wings. Such an airplane was outlined to the Aircraft Production Board with drawings and technical data in 1917, and marked the beginnings of our own experiments in actual construction of so-called thick-wing, or cantilever, monoplane-winged airplanes.

PROGRESS OF DEVELOPMENT

Our own analysis of the best methods of solving the problems outlined above can best be visualized by reviewing first the history of our work to date in thick-wing and finally in all-metal airplanes. Our original

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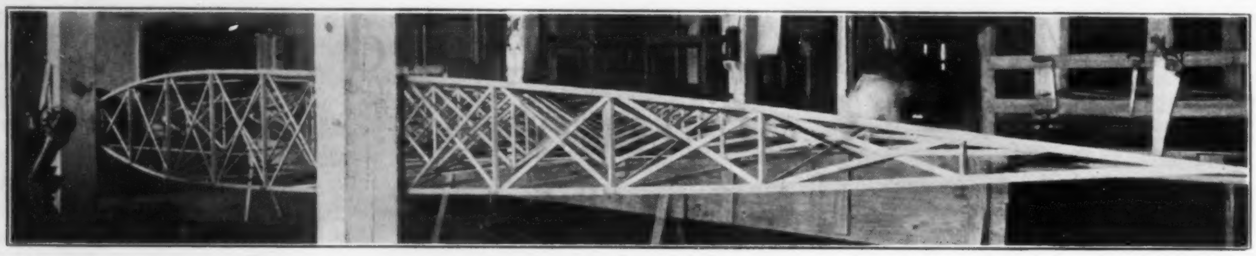

FIG. 1—FIRST MOCK-UP OF THE THICK-WING PLANE MADE IN JUNE, 1918

idea was that, if parasite resistances form two-thirds of the horsepower resistance of airplanes of that day, the first line of attack for the engineer to follow was to eliminate parasite resistance. The simplest and most obvious way was to make nothing but a wing and put

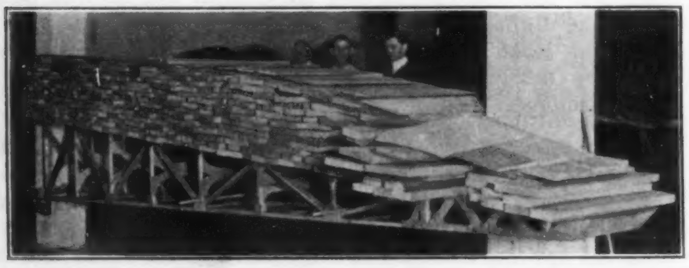

FIG. 2—FIRST CANTILEVER TEST OF A SPAR WEIGHING 7 LB. UNDER A LOAD OF 2200 LB.

everything inside the wing. Thus, for every pound of resistance to forward motion for which we must expend horsepower, we would get back 8 to 20 lb. of lift. To be able to do this would be to double or quadruple airplane performance at one jump.

Fig. 1 shows our first mock-up, built to show the idea we had in mind. This gave us a view of some of the engineering problems we were up against, and a peep into the new structural possibilities that had come with a search for mere aerodynamic advantage.

I will not follow our wind-tunnel research, or choice of a wing curve and the like. The type of spar was the first thing developed. Fig. 2 shows the wing spar as tested, supporting 2200 lb. of evenly distributed load from the root to the tip, the spar does not touch the outer post, and in a weight-per-spar of 7 lb.

Fig. 3 shows how the spars were fitted to the body and the general scheme of transverse structure. On proceeding with our patent work in connection with the structural progress we found that a similar fundamental had been in the mind of Hubert Latham of France, who had built a peculiar pouter-pigeon-like plane of thick-wing design which actually flew but was soon crashed. Latham, therefore, seems to have been the real inventor of the thick-wing plane later claimed and developed by Junker of Germany, but all from the same fundamental idea. Junker's patent views, uncovered after our first planes were in the air, showed an almost similar front view to that shown in Fig. 3, but it differed materially in other features. Latham's machine, however, antedates Junker's applications by several years.

When this work started, we had no thick-wing curves and we, with others, had the idea that a thick wing would have more resistance than a thin wing, forgetting that a wing's value is in the amount of air that it displaces, as well as its minimum of drag. Our first ship therefore was designed with a long thin curve with a fineness ratio of about 1 to 12. To get the wing thickness and still have depth enough for our spars, we lengthened the chord of the wing at the fuselage to extend the entire length of the fuselage, as shown by the photograph of the completed plane in Fig. 4. This gave us spar depth and structural advantage, but introduced problems of center of pressure movement that it took some time to solve even on paper. Fig. 5 is a front view of the same structure.

The airplane as shown had an area of 480 sq. ft., was made entirely of wood and three-ply veneer, the first veneer plane built so far as we know, and with a 150-hp. Hispano engine weighed complete but 1542 lb. It had retractable radiators, a full factor of safety of 6, and its lightness proved that at least we had hit upon a good structural fundamental even before we tried it in flight. This plane was hopped at Dayton at McCook Field in 1918 even though the engine we had been furnished had a broken pump shaft and hence could attempt no serious flights. The plane seemed normal as to lift and fore-and-aft balance. Its ailerons were ineffective and the

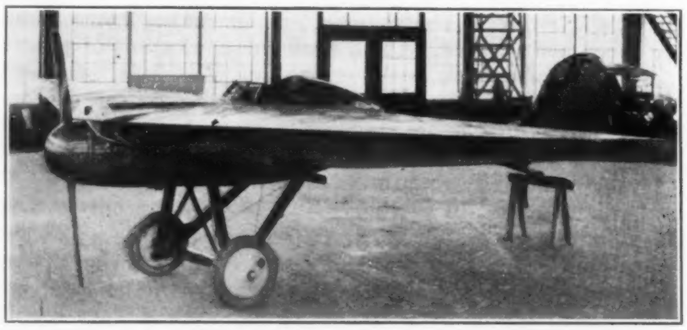

FIG. 4—SIDE VIEW OF THE FIRST VENEER BATWING AIRPLANE
The Area of This Plane Was 480 Sq. Ft., the Total Weight Was 1542 Lb. and the Engine Was a 150-Hp. Hispano

vision abominable. The lessons learned from this plane, however, were well worthwhile and led to the next step under civilian auspices after the armistice.

The war being over, we laid out and started a four-passenger commercial job along the same lines, but influenced by the lessons learned from previous work. A large number of changes were made for sales reasons, but it is my own opinion that the airplane of the future

FIG. 3—EARLY ARRANGEMENT OF FITTING SPARS TO THE BODY AND THE GENERAL TRANSVERSE STRUCTURE

will look more and more like the original "Batwing" as it was dubbed at McCook Field. The new design, however, using a small-lift, high-speed curve, had a gap between the tail and the long-chord wing at the demand of opinions, and had added a cabin and features to fit it to commercial use.

Fig. 6 shows the commercial sedan, also of veneer throughout. This plane, piloted by Bert Acosta, flew at the first attempt. The wing curve was poor in lift and the climb was bad. The pilot was enclosed and this was undesirable. The vision was not ideal.

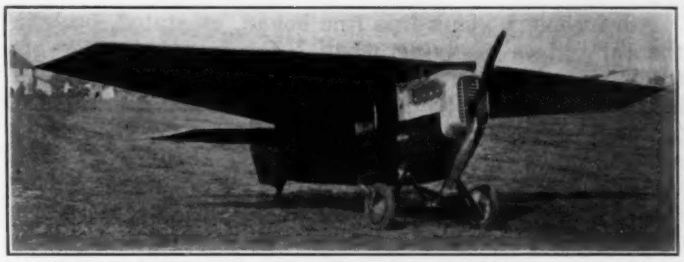

FIG. 6—THE FOUR-PASSENGER ENCLOSED SEDAN AIRPLANE WHICH IS DRIVEN BY A 200-HP. ENGINE

Our light-lift wing-curve had been chosen because of its small *CP* or center of pressure movement as we, and all of our advisers, were afraid of the action of the long chord with a really cambered curve. The poor lift of this airplane forced us to take it back to the shop, however, and change the wing nose to give us a really lifting-wing profile. Trials with this airplane, as changed, surprised us. We had more lift and climb than we expected. With a 200-hp. Packard eight-cylinder engine, the machine with 750 lb. of load made an official speed of 112 m.p.h. and climbed 4800 ft. in 10 min. It was a tricky flier, however, and in the glide "hunted" in a way to alarm any but a pilot of strong nerves and wide experience.

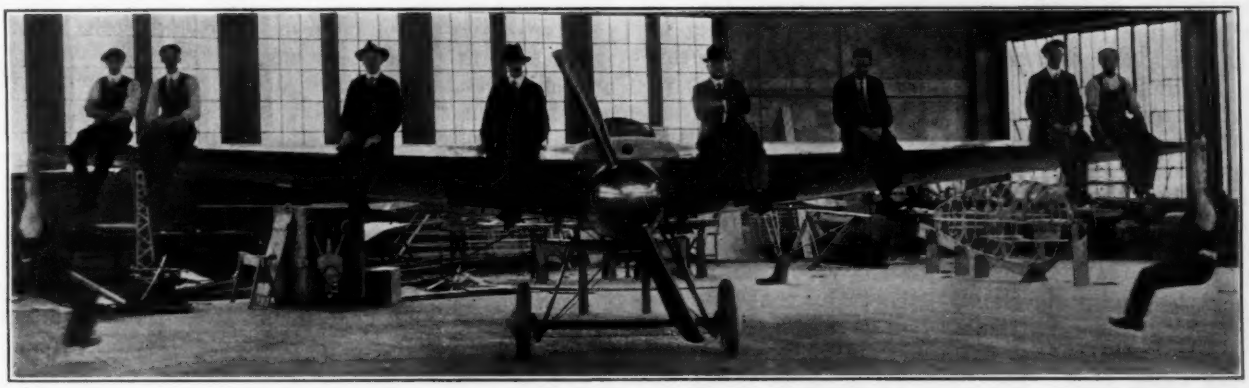

FIG. 5—FRONT VIEW OF THE AIRPLANE SHOWN IN FIG. 4

This airplane was flown from 30 to 40 times with a load and without, and with new tails, new flippers, larger and smaller rudders and what not, but still the hunting due to the *CP* travel continued. At last the idea came, and by a change not occupying more than 10 min. a new airplane was born. The hunting was cured, the controls all became more effective and the flippers too much so, and our "batwing" problems were solved. Later this 36-ft.-spread airplane flew with a 1070-lb. useful load, and got off with real snap and ginger. Our future large type commercial airplanes will be of this long-chord type, but of all-metal rather than veneer construction.

Following our experiments this far one can see that an original search for a new aerodynamic advance brought with it as more or less of a surprise a considerable advance in structural possibilities, so that it was possible to build lighter areas of the same factor of safety.

THICK-WING PROBLEMS

The entire problem in a thick-wing job seems to be not so much the strength of the spar members involved, as this is comparatively easy to obtain, but the *wing rigidity* so that there is no distortion or warping of the wing against aileron action, nor change of angle of incidence at the tips at different angles of attack of the plane. Foreign designers, particularly of the German school, have gone either to the thick-wing curves, such as the Junker, or to outside trussing, such as the Dornier. In the thick-wing Junker type, with an almost rectangular span of wing, the airfoil becomes so very deep at the fuselage in proportion to the chord of the wing that considerable speed is sacrificed to structural depth. To get the twist out of the wing, it is necessary to use very long interlatticed spars of more or less tetrahedral connection. This binds the structure into a solid unit but adds considerable weight, although, in the metal Junker, the wing is about the same weight per square foot as wood-and-cloth wings of the same general factor of safety and maximum spread.

In our type of wing we used a much more tapered plan view, so that for equal spar depth at the center section, as shown in Fig. 7, we had a wing of much better fineness ratio for high-speed work, at the same time the amount of structural space in the thick-wing, or German type of wing, extended only as far as the shaded portion *A* in Fig. 7; whereas, in our long-chord type, our structural space was almost three times the volume, as at *B*, allowing considerable advantage particularly for wing-tip rigidity. It was possible to build larger areas of equal weight by this method. The advantage of getting the greater amount of area toward the fuselage is obvious, from both structural and aerodynamic standpoints.

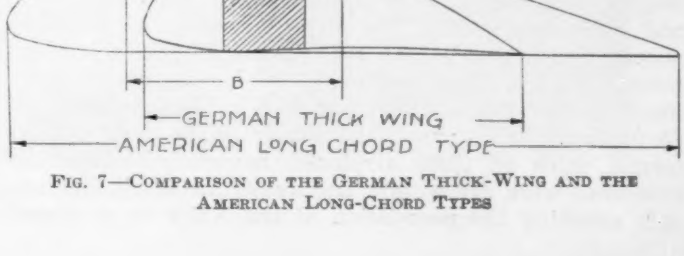

FIG. 7—COMPARISON OF THE GERMAN THICK-WING AND THE AMERICAN LONG-CHORD TYPES

Advancement along this line began, as stated, back in the early days of flying when Hubert Latham flew his thick-wing design with a fuselage on top and an enclosed landing gear, shortly after Bleriot made his famous Channel-crossing flight. The plane was crashed, however, after about its third flight and abandoned. Our experiments in this Country on the thick-wing type date from 1917 when we started, through the Aircraft Production Board, experimental activities on an airplane which, on account of its appearance, was quickly dubbed the "Batwing." So far as we now know, only one firm at that time, in any way paralleled the work we were doing. This was the Junker firm in Germany, which started its experimental work some time before our activities, but without our knowledge. Photographs show that the Germans started with the same type of wing-truss experiments as we later tried out in this Country, with the same method of building spars, mounting them and loading them, that is shown in Fig. 7. The only difference is that Junker worked in metal, originally in steel, instead of wood.

Starting from the same fundamental of enclosing as much as possible within the wing surface, Junker nevertheless adopted the old conventional arrangement of wings, fuselage, tail and rudder, and with the usual aspect ratio of wing, moment arm on the tail surfaces, and the like, making no attempt to produce a new aerodynamic plan other than that the wings should be thick and have the structure inside. The real original part of his development work was metal construction and all credit should be given to Dr. Junker for the very remarkable structures he finally developed, structures that are admirably suited to the particular type of airplane that he built, airplanes that have been flying in this Country under the name JL-6. Dr. Junker's work in metal indirectly grew from that of the Zeppelin Co. in duralumin in connection with dirigible construction, and it is only natural that it should be paralleled by the work of the Zeppelin Co. represented by its engineer, Herr Dornier.

Figuring also on a rectangular wing and noting the disadvantages Junker had in maintaining wing rigidity by the thick wing at the root to the limitation of speed, Dornier adopted a monoplane type using the same wing-spar thickness from tip to tip approximately, and a rectangular plan view of wing but fitted with outside brace struts, as shown in Fig. 8. This view shows the typical Dornier construction. The Junker, or JL-6 construction, with deeply corrugated metal surfacing, is well known in this Country, and it is doubtful if the Junker structure has been equaled in ships of its size.

Dornier obtained, by the use of a smooth section with inset ribs sticking above the surface every 8 to 10 in., a slightly better speed advantage but with no advantage of lift so far as the wings were concerned. In the end, through using external trussing, he obtained not quite so good a performance per horsepower due to the fact that his wings were heavier per square foot and that the airplane had more parasite resistance.

Another metal airplane, built by the Germans, was known as the Staaken Giant, a very remarkable, four-engine airplane, built originally to fly between Berlin and Friedrichshaven. The airplane was not a complete success due to overweight, but was a remarkable development. With a wing loading of 16 lb. per sq. ft., this machine flew successfully, but had a landing speed of 83 m.p.h. The Germans are not dropping their experimental work on these airplanes, however, because the first ones were overweight and faulty in detail, but are only awaiting the permission of the Allies to go ahead on further development structures. The Staaken Giant is the most pretentious example of all-metal structure ever undertaken. The Junker, however, as a commercial venture is the most successful.

All-Metal-Construction Requirements

I have used considerable space in explaining thick-wing design and the various schools involved, since it is this type of design that seems to fit all-metal construction best. To get the utmost out of the strength of the wing section, it is an advantage, with most of the designs to date, to use tapered spars so that the section itself can form part of the structure. In analyzing for all-metal construction in airplanes, there comes up at once a question of steel versus duralumin.

When we started our all-metal construction work, 2 years ago, little or nothing was known of duralumin, and designers were fearful as to its stability under conditions of weather, corrosion and vibration. Enough is known of it to-day so that we can speak openly and with knowledge of the real properties of the metal. As to the greater merits of metal versus wood-and-cloth, it is understood that in the statements I make I am voicing only our opinions as the result of our own experiments and accumulation of data during intensive work in this metal during the past 2 years, and the personal investment on the part of our company and associates of over $100,000. The properties of duralumin are stated in Table 1.

TABLE 1—PROPERTIES OF DURALUMIN

Specific Gravity	280
Weight per Cubic Inch, lb.	0.102
Melting Range	
Deg. Cent.	540 to 650
Deg. Fahr.	1,004 to 1,202
Modulus of Elasticity	10,600,000
Coefficient of Expansion	
Per Deg. Cent.	0.000002260
Per Deg. Fahr.	0.000001255
Yield-Point, lb. per sq. in.	30,000
Strength when Tempered, lb. per sq. in.	
Compressive	44,000
Shearing	30,000
Tensile	50,000 to 60,000
Elongation when Tempered, per cent	16 to 20

It is true that steels can be had of much higher tensile-strength per pound than dural, as duralumin has come to be called colloquially. It is also true, however, that these steels, heat-treated in very thin sections, are even more of an unknown quantity due to inaccuracies in the heat-treating, particularly in experimental structures, and therefore have variable physical characteristics. Dural, treated in a bath of nitrates at temperatures well under control and fabricated quickly before the tempering has begun to take effect, is thoroughly reliable and can be depended upon for a 55,000-lb. per sq. in. tensile-strength, with an 18-per cent elongation.

If steel spars are used in connection with dural structure, provision must be made for differences in the coefficient of expansion and for the production difficulties of riveting metals of different hardness. There is an advantage in making a complete dural structure in that no expansion difficulties are encountered, and production problems are much simplified.

Our first problem in building an all-metal airplane was the same as in building our first wooden one, the development of a tapered spar of sufficient strength for wing requirement. The contract we were working under required an airplane of 60-ft. span, maximum, and 600

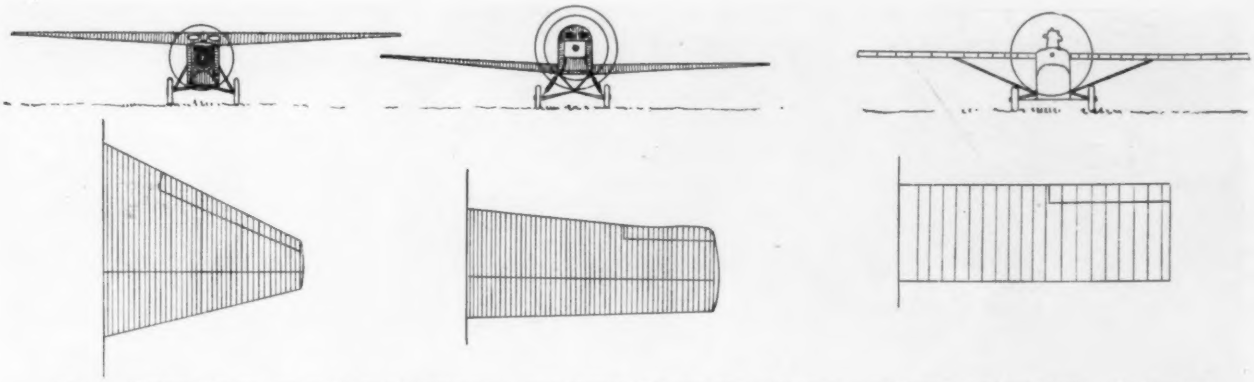

FIG. 8—FRONT VIEWS, FROM LEFT TO RIGHT, OF THE STOUT COMMERCIAL, JUNKER AND DORNIER AIRPLANES AND THEIR WING PLANS UNDERNEATH

hp., to be arranged either for wheels or floats, and to carry approximately a 2-ton load at 105 m.p.h. In the trials the airplane, with its full load, officially, made $113\frac{1}{2}$ m.p.h. and was the first American-built, all-metal machine to fly in this Country. Our "Batwing" airplane at McCook Field was the first thick-wing machine to fly in America, and possibly the first veneer airplane built on this side of the Atlantic.

The first requirement for the wing spar was the development of what we originally called the "spar longerons" but which later were termed "chord" sections. These are the top and bottom members of the latticed girder, as shown in Fig. 3. Development work was done on 19-in. hand-made sections, starting with the conventional U-shaped members and developing through the various convolutions, and changes found necessary in each until the master section developed, as shown in Fig. 9. The upper left view is the spar chord-section. In the 19-in. column this weighs $7\frac{1}{2}$ oz. and will support 8000 lb., or 4 tons. The longeron section, weighing about 4 oz. in the test column, and supporting in column load 4400 lb., is illustrated in the upper right corner. The drawing in the lower left corner is that of an ordinary U-section used for ribs, and that in the lower right is a special diagonal section for the lattice of the spar girders which, in the 19-in. column, supported 2100 lb.

In these pieces, the advantage of dural over steel was shown. The tension member is not the problem in building a spar; otherwise we could make our spars of piano-wire cable. The real problem is the compression member. Dural, being so light and with a much thicker section in proportion to its strength than steel, has a considerable advantage in rigidity, hence these light weights in proportion to the strength. Our entire airplane substantially was made up from these four sections in various arrangements, and with different fittings and connections. Aside from the fact that the parts were all metal, the general structural arrangement and spar

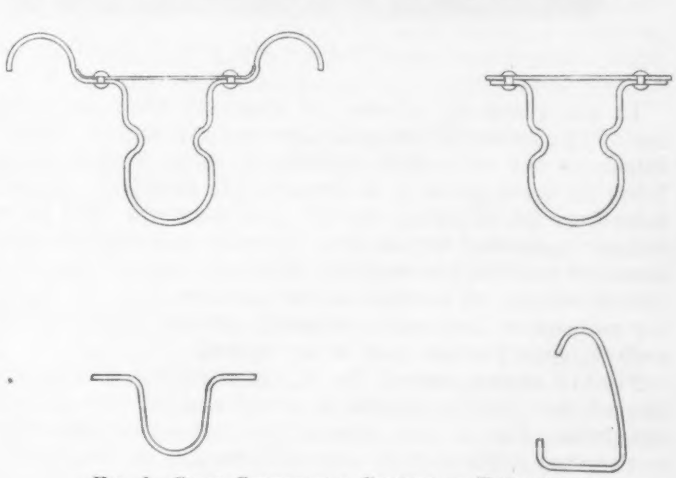

FIG. 9—SOME STRUCTURAL SHAPES OF DURALUMIN

layout followed very closely the airplanes we had previously built in veneer.

The Junker airplane uses dural tubing for spars and places these, with diagonal latticing between and stamped from dural sheet and riveted in place. The Dornier uses the U-shaped spar-members with side plates and with plate ribs running fore-and-aft between each, the flat surface pieces with their upturned edges being left to form external ribs. The Staaken Giant used metal of a heavier gage, flat sheet for surfacing with plate ribs inside. Both the Dornier and Zeppelin or Staaken designs were heavy compared to the Junker.

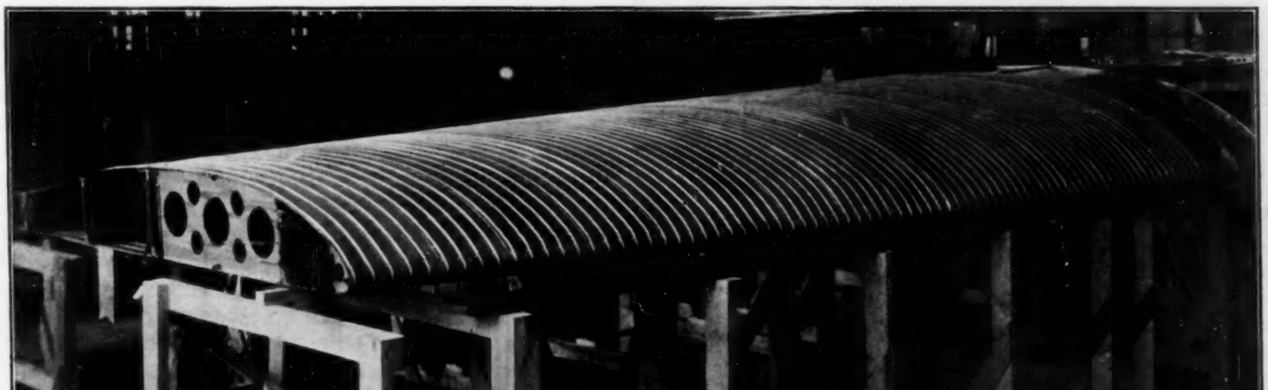

FIG. 10—AN AIRPLANE WING THAT WAS CONSTRUCTED ENTIRELY OF DURALUMIN

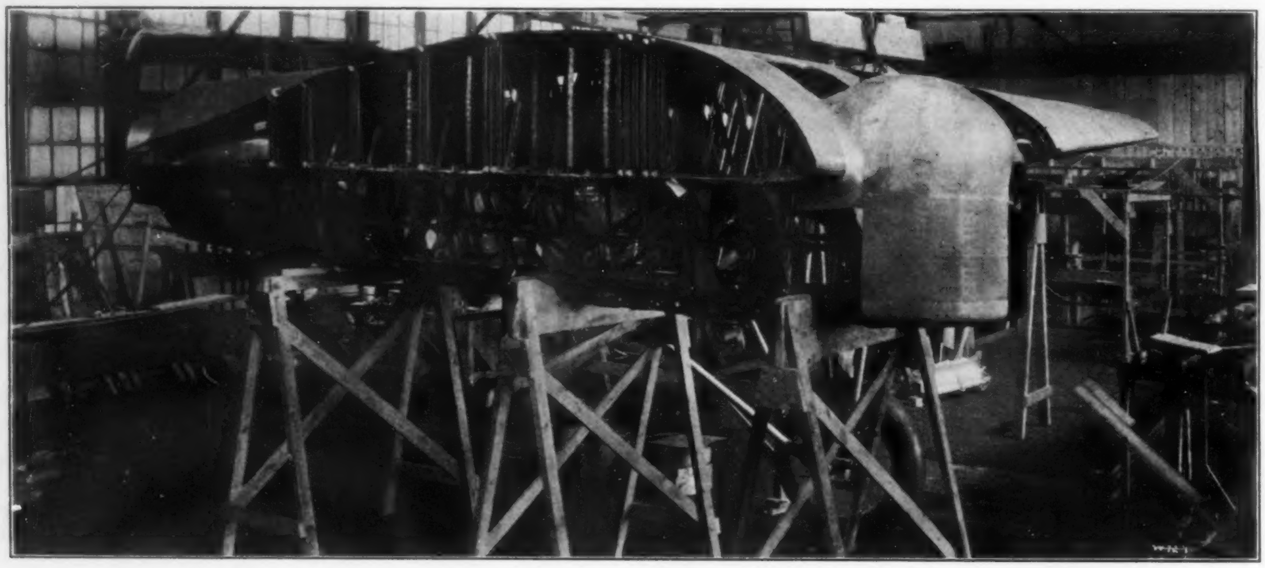

FIG. 11—A SIDE VIEW OF THE FUSELAGE IN COURSE OF CONSTRUCTION IN THE SHOP

In our plane we allowed 10 spars by their depth to form the contour of the wing fore-and-aft, and by merely attaching our wing skin of 0.020-in. dural, ribbed every 2 in., to these spars in a fore-and-aft direction, we obtained wings of great rigidity and strength, and in a weight equivalent to the best Dornier and considerably ahead of the Staaken weights, although heavier than the Junker wings, on account of our greater area and loading per square foot made necessary by our limitation to a 60-ft. span for the load to be carried.

Fig. 10 shows one of the wings complete, giving an idea of the smooth contour obtained and the size of the structure. Fig. 11 is a view of the side of the fuselage in the shop. This shows the arrangement of the spars, and gives an idea of the wing curve, the pilot's position and how the fuselage is divided just back of the wing for storage purposes. The weight of the airplane complete and fully loaded approximates 5 tons. Table 2 gives the comparative areas, weights and the like, of other metal airplanes previously built.

TABLE 2—COMPARATIVE AIRPLANE DATA

	Dornier Comet	Dornier Dragonfly	Junker	Stout Ordinary	Stout Commercial
Span, ft.	58	28⅙	49	60	35
Length, ft.	30	23½	29	..	31
Height, ft.	8	7⅚	10	..	10
Area, sq. ft.	459	150	417	790	280
Chord, ft.	9	5¼	8½	13½	8
Weight, Full, lb.	3,960	1,652	4,101	9,817	2,025
Weight, Light, lb.	2,500	992	2,341	6,557	1,250
Useful Load, lb.	1,460	660	1,760	3,260	775
Useful Load, per cent	36.5	0.4	43.0	33.0	34.0
Engine Type or Size	BMW-233	80 hp.	BMW	600	90-OX
Wing Load, lb. per sq. ft.	8.65	9.70	9.60	12.40	7.20
Weight per Horsepower, lb.	17.0	20.7	17.4	16.0	22.5
Useful Load per Horsepower, lb.	6.2	8.2	7.2	6.1	8.6
Ton-Miles per Gallon	3.10	..	4.25	3.61	4.40

SUMMARY

All metal planes, to date, can be called experimental. The future commercial airplane, however, will undoubtedly be an all-metal construction. Metal planes mean greater safety to pilot and cargo; a possibility of considerably lighter weight; less production cost, particularly as quantities go up and the demand increases; and easier servicing and simple repairs provided the airplanes are designed with this idea in view.

It cannot be expected that the first metal-construction attempts of any manufacturer will be a success in every particular but, if America is to lead in aircraft, it must lead in metal aircraft, as it is my opinion that, in a comparatively few years from now, wooden airplanes in the air will be scarcer than wooden ships on the sea, and that all airplanes flying under insurance rulings will be of all-metal construction.

Thick-wing airplanes are developing fast, both in monoplane and biplane types. Retractable chassis, wing-type radiators and all those items that the recent Pulitzer events have shown to be practicable, will appear shortly in commercial airplanes and increase their profit-paying possibilities. But if safety and low cost are to come with these items of greater performance, then must metal construction and production methods be applied to the producing of an airplane for American air-services that shall be safe, cheap, economical and long-lived. Only by the production of a real commercial airplane can commercial aviation come in America.

THE DISCUSSION

COM. H. C. RICHARDSON:—I am unable to agree with Mr. Stout in his conclusions that "the eventual airplane will expose no parts to the air that do not give back lift in return for their resistance." The statement is not incorrect, but the inference to be derived from it is incorrect. At least I infer that Mr. Stout intends that no elements are to be exposed which are not designed to give lift in a normal attitude. Practically anything but a sphere will give a lift if properly set to the wind, but very few shapes give lift efficiently except wing-shaped sections. Struts, floats and fuselage sections can approximate wing-sections in form, but in most cases the aspect ratios are bad and the lift-drift ratios are not high. Any attempt to give them lifting sections will result usually in an expansive life on this account; whereas, to give them minimum resistance, but little lift is sacrificed and, in a normal attitude of flight, their resistance is lower than would be the case if made a lifting section. That the aerodynamic qualities must be as clean and efficient as

possible and that the structural design that offends against this must be modified is, I believe, recognized by anyone familiar with aircraft design. The parasite resistance must be reduced to the lowest factor compatible with the purpose of the design, and this implies structural efficiency. But questions of stability, maneuverability and arrangement require that an aircraft shall be more than wings alone, and the additional members, I contend, will be more efficient if carefully streamlined and carefully disposed to meet the conditions of maximum performance, than would be the case if the attempt were made to get a lift as the prime feature in the design of these elements. I believe it better to gain a lift from the most efficient lifting member and to give the parasite members the best streamlining possible.

Present practice indicates a minimum wing-drag at from 2 to 4 deg., but when this is associated with parasite resistance the minimum drag for a complete airplane is usually found to be at from 8 to 10 deg. With thicker wings, these data require some modification, as some of these sections are most efficient at angles in the neighborhood of 0 deg.; but the effect of additional parasite resistance will be of the same nature as that indicated. In still air the maximum efficiency for cruising is at an angle of attack of about 7 deg., and this angle changes very little with the load carried. From this it appears that it is of paramount importance to commercial craft to dispose the fuselage for minimum resistance at such an angle of the wings. Depending on the purpose for which an airplane is designed, there will be an optimum angle for the wing setting to give the best result whether it is climb or speed, or some other quality that is considered most important; and this should be given consideration in locating the wings on the fuselage so that the resistance of the fuselage will be a minimum for the chosen condition. Relative to wing efficiency, I am not unaware that a head or a tail-wind will change the optimum angle for cruising, but the slight variations involved will not affect the fuselage resistance seriously.

For the time being it appears that the wing loading which can be used is controlled by getaway and landing speeds; but, for commercial aircraft, I believe the greatest efficiency of transportation requires high power-loadings, although here again is a limit, as the design must not be sluggish. To combat head winds or bad air requires a reserve of power, and that means a reserve of speed and of fuel and oil. There is, therefore, a limit to power loading, and I place the desirable maximum speed at least 50 per cent above the landing speed and preferably 100 per cent above it.

We still have something to gain in propeller and engine efficiency, and much to gain in structural efficiency. Regarding structural efficiency, I believe we may well haul in our horns on the factors of safety and gain a worthwhile improvement in useful load without danger. A factor of safety of 4 appears ample, and even 3 should be sufficient for a carefully designed airplane if the pilots will confine their maneuvers to those required for commercial purposes and avoid stunting. Bad air and forced landings require consideration, however, in determining this reduced factor.

I believe in metal construction and that ultimately it may replace wood and wire, but it requires much research. I believe it will be warranted on a production basis only. Both research and production to be warranted require established service and a demand incident thereto, and I believe that both will develop more rapidly with the demonstration of efficient wood-and-wire construction than can be hoped for in the immediate future from metal construction. Also, it appears that, for the present, the light alloys have an advantage over steel, because the thicker sections used for equal strength have greater resistance to secondary failures.

Maintenance is important and it is here that metal offers important advantages from a deterioration standpoint but, from the viewpoint of field repairs and minor crashes, I anticipate much anxiety in regard to a metal venture until a production basis is reached and readily available spare units permit damaged parts to be replaced easily so that they can be returned to central shops for repairs where heat-treatment and proper facilities are available.

I congratulate Mr. Stout on his paper, but more on the valuable experience he has had in this pioneer work. I congratulate him on his vision and faith and persistence, and truly hope he will see and participate in the development that is bound to follow the efforts which have required no little financial and personal courage. He has important assets in his experience which I hope will materialize to his advantage and to the advantage of aeronautics.

HARLAN D. FOWLER:—Refinement in the detail design of structural parts sufficient to develop the required strength demands experience and good engineering principles. It was necessary in the past to construct portions of an airplane of more than the necessary weight to insure proper strength. This was due to the uncertainty of the conditions to be met. With sand-load and flying tests as they have been developed up to the present, it is possible to design parts that have just sufficient strength and so obtain a very light member. An example of this is the hull of a flying-boat. The conditions met with on landing, porpoising, taxiing or getting off are uncertain quantities. The British made some very difficult tests[2] in 1920 by subjecting the hulls of the F-3 and the H-16, weighing respectively 10,600 lb. and 11,600 lb., to all of these conditions; and, by ingenious measuring devices, they were able to determine local and distributed stresses along the entire bottom of the hulls ahead of the step. These measurements revealed the localities where much excess weight could be eliminated, and this is one reason so many of the seaplanes have poor useful-load capacity. Within narrow limits, a seaplane should be as light as a land machine.

We are greatly concerned with the reliability and durability of our engines. The attempt to develop large power and light weight is justifiable for military purposes. But are they practicable for commercial usage? At present it is necessary to have a large reserve of airplanes on hand to maintain regular service such as existed in the Forest-Fire Patrol on the Pacific Coast. It was necessary there to have at least three machines tied up to keep one in the air, and the greater number required engine attention. The vertical type of engine represented in the German machines certainly gave more uniform service.

In the last few years a very important phase of development has been recognized as being essential to increase the usefulness of airplanes. The rigid or inflexible type of wing construction must be relegated as belonging only to the past progress of the art. Efficient as thick wings may be, the advantage of the variable area, variable camber or auxiliary wing-surfaces presents too great a possibility to be allowed to lie dormant much longer. To obtain a safe landing-speed or to get off with a heavy load, we are obliged to carry a certain amount of excess wing-

[2] See British Advisory Committee for Aeronautics Report and Memorandum No. 683.

surface and an inflexible wing-section. Having once cleared the earth, why do we pack with us on a journey occupying hours all of this parasite or airfoil resistance that demands such unnecessary power as the cube of the speed requires? It is apparently something we must rid ourselves of very quickly. It is also apparent that the variable area is one of the most important features offering the most substantial gain. There may be some mechanical difficulties at first. So also there was difficulty with the first automobile gearshifting device, which is closely analogous to our problem. To be able to increase the passenger load 100 per cent, or to reduce the power required 25 per cent, or to increase the high speed 20 per cent, or to reduce the landing speed 15 per cent, certainly offers an interesting goal.

With few exceptions for steel, there is no doubt of the advent of the duralumin airplane. The lightness, strength and ease of handling of this metal eventually will simplify our constructional problems. With experienced workmen and the gradual increase in demand for duralumin tending to cheapen its manufacturing cost, it will be a serious competitor with wood. As Mr. Stout points out, duralumin is no longer a metal of mysterious properties. Aside from exercising care in the annealing and tempering of this metal, it is nothing more than a high-class tinner's-job. To see the use of this metal in the framework of the ZR-1 airship under construction at the Naval Aircraft Factory at Philadelphia is very conclusive evidence of its possibilities. If a suitable brazing compound could be found, the use of duralumin for fittings would be more extensive. However, duralumin in the forged state has been used, to a lesser degree, with some success.

H. M. CRANE: — I know from past experience with light-boat construction and similar work that it is essential that every bit of material in a light structure bear its just proportion of the load. If you intend to have a factor of safety of 6 and there is a large part of the structure that has that factor and another large part that really has a factor of 2, the structure is inefficient.

The most difficult feature of any problem of structure is the design of the compression members. The Quebec bridge disaster was due solely to failure of the compression members. The failure of the dirigible R-38 was caused unquestionably by the failure of a compression member. The joint between the different members is another important detail. When dealing with thin sections of metal, it is very hard to make sure that the load is distributed over the whole structure. It is very apt to be very much localized, with a certain attending failure. You can make tests on 19-in. pieces in a testing machine and get an excellent line on what you must do; but when you design a 70 or 100-ft. span on an airplane, it is very difficult to translate the results of the 19-in. tests into terms that apply to the full length of the machine. It is equally difficult in construction to see that each of the hundreds and hundreds of pieces that go into that wing is really bearing the load it is designed to carry.

The fact that the winning machines in Detroit were all American machines from the engine, the radiator and the powerplant installation to the whole airplane construction, is a thing that we all can be justly proud of. I felt during the war, and it has been proved since, that the sooner we in this Country stopped looking abroad for inspiration and began to look at the airplane and the airplane engine from our own point of view, the sooner we would progress. I believe that, with the opportunities this Country has had, the progress in aviation has been astounding. That does not apply to commercial aviation, but I think we ought not to feel too much discouraged about commercial aviation. Commerce is a traffic, it is a barter and trade that is healthy and of real value only when something of value is sold to somebody who requires that thing.

The Aeromarine Airways, Inc., has made a strong start in that direction, taking the most favorable opportunities where the competition with other methods of transportation has been reasonable. The Air-Mail Service is making a record from day to day that is being surpassed nowhere. This is being done with a very moderate amount of support from the Government and by using salvaged machines.

The Liberty engine has been one of the most adversely criticized powerplants that was ever produced, but its history proves that it is probably the most remarkable feat of design and construction done by any country during the war. The first race at Detroit was between five Martin bombers, each powered with two Liberty engines. The winning machine averaged 105 m.p.h., the difference between its fastest and slowest lap being less than 0.5 per cent. The other four machines, while not so fast, ran with almost the same degree of uniformity. A Liberty engine recently drove an airplane for 35 or 36 hr. consecutively, raising the duration record in the air something like 12 hr. over the previous record made with a German engine.

HENRY E. BRUNO:—During the 3 years in which we have flown more than 1,000,000 passenger miles and carried over 20,000 people without a single serious accident, we have demonstrated that commercial aviation in this Country, so far as over-water flying goes, is not behind that of Europe. We inaugurated the first double daily service between two large cities in the United States in the summer of 1922. I refer to Cleveland and Detroit. We used three 11-passenger enclosed-cabin ships; two were in active service and one was in reserve. We started our double daily service July 17 and finished Sept. 17. We had no forced landings, no interruptions of schedule, and the boats left on time twice daily from each end of the route. The first 2 weeks these big 11-passenger boats carried about four passengers. It was heartbreaking to send those ships across the Lake that way, but we realized that we had to prove something to the people of Cleveland and Detroit. Toward the end of the service, we could not accommodate the people who wanted to fly.

CHARLES M. MANLY:—Mr. Stout has hammered steadfastly at the very important subject of parasite resistance. He awakened a greater realization of the enormous importance of parasite resistance when he indicated what a large portion of the total resistance of the DH4 machine is parasite resistance. Mr. Stout has wanted to put everything inside the wing. Commander Richardson questioned whether that may not be carrying it a little too far and pointed out the importance of streamlining certain portions and possibly leaving them exposed in their more efficient form. The importance of doing one or the other is very firmly established by the results of this speed test at Detroit. At an air-speed of 248 m.p.h., every square inch of normal surface has a pressure of 1 lb. on it. The winning machine, with the horsepower that was required to propel it at 248.5 m.p.h., was really experiencing a total head-resistance of very little more than 3 sq. ft. of normal exposed surface. That brings home to us very forcefully the advantage of minimum parasite-resistance and the importance of applying accurate scientific data and thoroughgoing engineering training and experience to the design and construction of a machine.

HERBERT CHASE: — Why did Mr. Stout give up the veneer type of construction in favor of the all-metal.

WILLIAM B. STOUT:—In figuring on commercial aviation and on safety and cost as the fundamentals of commercial aviation in comparison with maneuverability and some other things for military ships, our analysis was that metal would of necessity be the eventual material, if only to secure safety in crashes. Airplanes must operate in all climates. For Europe or for our Northern climates I think a veneer ship would be fine, but in a hot climate such as that near Mexico, where the casein glue would harden and the veneer dry-out and split, veneer is out of the question. Also, I would rather trust metal and rivets because it has been demonstrated that there is less possibility of serious personal injury in a crash.

I disagree with some of those who have spoken on the cost of metal construction. I admit that the experimental work we have done to date is expensive. But, having been through that, we know now how to design more economical structures. I believe that we can repair our newer-type structures in an emergency practically as quickly as we can repair wood.

Another advantage in all-metal construction is that the entire airplane can be made of comparatively small units. You save cost in the shop and, if you damage a unit, it is generally cheaper to replace it than it is to fix it. I believe that to-day we can build airplanes of certain passenger or load capacity more cheaply than we are now constructing passenger cars and motor trucks of the same capacity, up to 1 ton, if we can market them in equally large quantities.

We are flying now with one Liberty engine and carrying loads that required two Liberty engines during the war and at higher speeds. The airplane that made the world's endurance record recently left the ground with some 4200 lb. of gasoline aboard. Its engine had the same horsepower, practically, as that of the airplane that made the 248-m.p.h. speed; so, we are translating horsepower now not only into tremendous speeds, but also are able to translate the same horsepower, if we wish, into load carrying at slower speeds. I think we will see within very few years a nice four or five-passenger commercial airplane selling for less than $3,000. When we do see that, I think commercial aviation will have begun.

LEON OTTINGER:—It is only recently that really scientific work has been done in the manufacture of plywood in our different lines. For instance, the veneers are being chemically tested after being cut. It has been found that they can be treated chemically so as to wash out the cells fairly well. Then they are treated with chemicals that lower their coefficients of expansion and contraction to a very marked degree, when under the influence of either water or heat, without injuring the strength of the individual veneers. That is very important because the ability of plywood to withstand weather, due to the waterproof glue, means that the glue, in its soaked condition for instance, should be stronger than the expansive power or stress produced between the various parts of the veneer. If the veneer is reduced, the plywood will stay together with a weaker glue. Furthermore, the stresses on the various structural parts of the airplane must be definitely effected by a plywood that will not expand or contract to the extent that the old types of product did.

The matter of what woods to use for making the veneers and the manner in which they are cut provides a large field for research in plywood. I have seen a number of braces made of chemically treated plywood; the process is of German origin. The veneers were used before being fabricated, but I have seen pieces of that kind that had an angle of 90 deg. thrown into the water, and that remained at an angle of 90 deg. when taken out and dried. I think that the lack of development of plywood has been due partly to taking emergency Government specifications too much for granted; the plywood factories have not developed anything new in the way of airplane plywood, because it is very poor judgment to alter material from specifications on Government orders.

S. WARD SEELEY:—I believe the time is coming when radio telegraphic equipment will be as essential on an airplane as the landing-gear, for instance, and in view of the fact that all-metal equipment might militate against the successful employment of radio equipment, I am wondering whether Mr. Stout has made any tests on the effect of the all-metal construction on radio signals?

MR. STOUT:—No, we have not. However, I think that would have about the same relation to the development of metal airplanes as the question that came up when iron ships were first made, that the compass would not operate properly, and that therefore it would be useless. I think the radio will be the compass of the airplane and that every airplane will of necessity be equipped with it to travel through fogs and any kind of weather and for night flying. The radio engineers undoubtedly will solve any interference problem.

I believe that a factor of safety of 4 in a metal airplane is safer than a factor of safety of 6 in a wooden airplane. But if you intend to build in wood, I think plywood is the thing for the cantilever type of airplane. Since the wooden members that are used are of such small section in multiple units, if they are made of plywood, you know you have a pretty good average in the piece anyway, although the piece of plywood in itself will not pull as well as the best piece of spruce you can find; but it can be depended on to have uniform strength.

H. E. DAVIES:—Does Mr. Stout consider the riveted seams a source of weakness?

MR. STOUT:—No, provided the riveting is watched to be sure that it is a thorough job, and that the duralumin is watched when the holes are drilled so that no cracks are started. If heat-treated duralumin starts a crack, the crack is liable to run, just as with any tempered steel. We ream all of the holes after drilling and before we rivet, and are very careful to start no cracks and get as perfect riveting as we can.

HENRY R. SUTPHEN:—What effect has salt water on duralumin?

MR. STOUT:—In the natural state, duralumin is affected by salt water; in the heat-treated state, normally, it is not. I should say it is affected about as much as iron is with water. Some rust or surface corrosion comes but, when properly heat-treated, we have had absolutely no trouble with it. It is perfectly possible to weld it, but the welded joint seems to go back almost to aluminum and is not rust-proof. Salt water will affect it. We have put pieces of duralumin into a saturated solution of salt water for 3 months without having the metal destroyed; in fact, it showed practically no signs of corrosion. We hear from other sources that salt water does have effect, but we have had no trouble ourselves with corrosion of any kind.

MR. SUTPHEN:—Is that the reason you rivet the sections?

MR. STOUT: — Yes. We rivet the sections and heat-treat the rivets. One thing about the metal is sometimes confused with corrosion. In some of the very thin sheets from the German airplanes, what appears to be corrosion in spots where vibration has occurred can be noticed.

That is where parts are over-stressed through poor design. It is due to the fact that the metal in these airplanes was obtained during the war, when Germany could not get pure aluminum to make the duralumin, and there was too high a content of zinc in both the copper and the aluminum. When zinc is present in any aluminum alloy and there is vibration, the metal will tend to granulate. Under that condition, there is trouble. It looks like corrosion, but it is due to the presence of zinc in the aluminum. That is why our American duralumin seems to be superior to the foreign duralumin; we have a pure aluminum to start with, and at least as good copper, if not better.

MR. CHASE:—Does duralumin suffer from what is commonly called crystallization or fatigue to any greater extent than other metals? How does the metal construction compare with wood in respect to durability, when affected by vibration?

MR. STOUT:—As with any metal structure, that depends very largely on the design. For example, with any alloy-steel, if it is located at a point where there is too much vibration and overstress on the metal, there is bound to be an effect on the metal in time. The idea that duralumin becomes fatigued and crystallized by vibration originates from faulty design.

Regarding the metal floats, water soaks up in the wooden floats after leaving a seaplane standing in the water for 3 months. The actual soakage is about 600 lb. for an F5L hull. With a metal float, that weight could be saved and put into the pay-load at a certain amount per pound.

COMMANDER RICHARDSON:—We have not gone extensively into vibration tests at the Naval Aircraft Factory, but we have information that vibration is just as important with duralumin and no more important than it is with other metals. The elastic-limit must not be exceeded and so long as the stresses are maintained at a moderate value, there is no reason to suspect that duralumin will give way any more than any other metal.

MERRILL C. HORINE:—It has been my impression that duralumin is more economical to work in building a complete airplane than the conventional wood, wire and fabric.

MR. STOUT:—That depends upon the design. If an attempt is made to reproduce a wood, wire and fabric design in metal, it will cost a large sum of money; but if the structure is designed to suit the material that is to be used, and the cheapest production processes that fit that material are employed, the structure can be designed and made so that it will be as cheap or cheaper than the wood constructions, even in experimental ships. However, if the design calls for a lot of bumped work and toolmakers' work and equipment of that sort for the first airplane, the costs will run up far higher than those of any wood construction. It is all a matter of engineering.

THE NEED OF RESEARCH FOR THE TRACTOR INDUSTRY[1]

EVERY commodity must meet an economic need in our lives and in industry, to be worthy of, and to win, the support of the buyer and consumer. That economic need may be manifold. The commodity may fill a need that adds to the health and happiness of a community by giving people a diversion from the deeper and more strenuous problems of life, or it may be purely economic in its effect on industry itself. The tractor, no doubt, can be classed only as filling purely an economic need in industry and, in so classing it, we must be sure that it fills such a place. It may be going far and it may shock many to question that it actually is filling such a place to-day.

For some time I have had a vision of research for the tractor industry. Perhaps others are having the same thoughts. The possible development of this dream of the future calls for research of a somewhat different nature than is ordinarily talked of in laboratories and factories. To most of us, engineering research means a highly technical study of some phenomenon, the fuel problem or the study of the operation of some new device in its adaptation to work. The thought I have is back of all of this and means a restudy of the old problems.

Before the tractor became a factor in the agricultural world, the methods or processes of the agricultural industry were pretty well established; therefore, the one chief thought of the man who was trying to introduce power farming was to make a machine to replace the horse. So the machines were made and the adaptation of these machines to the work became more or less an after-study. To the credit of the tractor industry, this adaptation has improved year by year and a closer study has been made of farming operations to develop a more universal type of power unit. The big problem before the advocates of power farming to-day is how to put farming on an absolute power basis. Until this can be done, I believe that the advocates of tractors cannot really come into their own.

To get at this problem, therefore, I can see a research farm; not one where tractors alone are tested and not where present-day horse-drawn implements are pulled by tractors, but where there is truly a research into every farming operation to see if certain of them cannot be dispensed with and replaced by others more adaptable to power farming; where certain types of equipment can be changed or redesigned to make them more adaptable; and where different types of power unit can be tested and studied to see what type lends itself best to all farming operations. The final result of such a course of research should be, if necessary, an entire turning-over of present methods into a new and standardized type of power farming which may consist of a new series of operations on the farm, perhaps done by a new type of implement and a new standard form of tractor if that is what this research may develop.

The problem of research must, of necessity, be very complicated. It must start from the bottom, with the agricultural engineer if you please, and not at top with the mechanical engineer. Comparative studies must be made of the economics of different processes and the results obtained. Unit costs must be kept on every detailed operation and these plotted as accurately as the finest cost-study ever devised in an industrial plant. Engineers with inventive ingenuity must be prepared to meet every operation with some solution from the power standpoint; for, to make a success of power farming, it will not do to try to replace horses in all the operations and then have to have horses to help with the threshing or some of the other operations. Records to-day show that the tractor does not actually replace the horse on the farm anywhere near in proportion to its initial cost.

We all ask why the tractor has not become standardized as the automobile has become standardized, but it seems that it cannot become standardized in the same degree because of the varying problems it has to meet. Some day what I have outlined will be done. Shall the day come after years and years of gradual evolution, for there is one correct solution and our individual researches will gradually lead us to it; or shall the tractor builders cooperate in finding the solution and hasten the approach of that day as much as possible?

[1] From an address, before the Minneapolis Sections December 1921 meeting, by Emil F. Norelius, consulting engineer, Minneapolis.

Questions Answered by the Research Department

MANY of the inquiries answered by the Research Department are of much general interest and involve a considerable amount of thought and research. For the information of our members a few of them will be published each month. It is hoped that in this way those members who have not yet availed themselves of the facilities offered by the Research Department may be encouraged to take advantage of them in the future.

PISTON-RING MATERIAL

Question:—As you are well aware, the question of piston-rings and piston-ring design has been the bête noir of engineers and metallurgists. We are anxious to arrive at some definite conclusion, first, as to the best iron to be used and, second, as to the necessity for mechanically improving the physical properties of this iron after it is made. To do this, we would like to know just what each manufacturer of piston-rings is doing at the present time, the sort of iron that he is using, whether made in the electric furnace or a cupola; the analysis to which he is working; whether his rings are pot or individually cast and the means used to increase mechanically the tension of the rings after manufacture. Possibly you may know of someone who has this information available, but if not, do you not think that a committee on piston-rings and their standardization would do considerable good?

Answer:—A letter was sent out to a number of piston-ring manufacturers, quoting the substance of this letter. We had originally planned to group this information under the four heads suggested but found the material we obtained was of such value that we decided to quote the letters as they were received, omitting the names of the manufacturers, believing that a copy of the letter in each case would be of far greater interest and value than an outline. Three of the replies that cover the main points of interest that were brought out are given below substantially as received.

> We agree with your correspondent that the question of piston-rings and piston-ring design has been a "bugbear" for engineers and metallurgists, but we are not so sure that he will arrive at a definite conclusion unless he gives the piston-ring manufacturer something definite to work upon.
>
> The problem that has confronted us, and we presume that it is common with other piston-ring manufacturers, is that the automotive engineer in many instances has expected the impossible from a conventional type of piston-ring. Engines are designed to accomplish well-defined results and the piston-ring, which is one of the most important factors in attaining these results, is very often given very little attention. All too frequently, blueprint specifications for piston-rings are determined in the drafting-room, rather than on the experimental floors, and when the size is thus determined the requirements are turned over to the purchasing department and a canvass is made of piston-ring manufacturers to determine where the product may be bought at the most advantageous figure.
>
> Then, there are those among the engineering fraternity who have been sent abroad by their principals to observe European practice, and upon return to their own factory have adopted Continental methods that are, perhaps, in no wise suitable to American road conditions. Desirous of reducing internal friction to the minimum, rings of extremely light tension often have been specified by American engineers, giving little thought to the fact that American automobiles are expected to negotiate roads absolutely unknown to the European car-owner.
>
> We believe that tension should be an inherent part of the ring, and submit as an obvious fact that the automobile engineer would not permit the use of any other bearing in his engine which, in order to fit, must of necessity be "Pittsburghed."
>
> We know of no manufacturer of any importance in the trade now offering pot-cast rings. Some of the multiple-piece rings, because of their construction, must be made of pot castings, but multiple-piece rings, so far as our information goes, are not being used by automobile companies as original installation.
>
> Prompt seating of piston-rings is desired on the part of many manufacturers, and various suggestions have been offered along this line. Some companies produce what is known as a turned ring, but in our opinion a ring that is soft enough to turn will continue to seat indefinitely and thus lose its tension within a very short time. To accomplish quick seating, we have devised what we call our Quick-Seating Ring. This comprehends the grinding of a channel in the central face of the ring approximately one-half its width and about 0.002 in. deep. This throws up a web on each side of the ring which wears down quickly and permits the ring and cylinder to attain harmonious surfaces within a comparatively short time. This channel ground into the central face of the ring does not throw it out of balance. Pressure is exerted equally over the entire ring width, but focused during seating on the raised edges and, as soon as these webs seat, further seating, except for normal wear, ceases automatically.
>
> In our opinion the exact specifications for piston-rings must be determined by tests made by the engineering department of the apparatus in which the ring is to be used. It is, of course, important to determine the type of ring to be used. Some manufacturers favor the diagonally cut ring, but others have a pronounced leaning toward what is known as the step-joint type. Some manufacturers who have used the former contend that with the sort of help usually available for installation, and especially in service-stations, if sufficient tolerance is not allowed between the points of the ring the expansion due to rise in temperature will in such cases cause cylinder scoring, while the use of the step-joint type of ring can produce nothing except perhaps abnormal but uniform wear on the cylinder.
>
> Tension or lateral wall-pressure is another important factor to be determined by the automotive engineer. It is desirable to reduce internal friction to the minimum, but some engineers have gone so far in this direction that oil-pumpers have been developed, and many devices have been employed to overcome oil trouble, whereas a few pounds additional lateral expansive effort in the piston-ring would have prevented the trouble. Tension may be secured in one of three ways; increase in width of ring, increase in thickness of ring or increase of amount to be removed when the ring is split.
>
> There has been a tendency lately among some manufacturers to adopt a very narrow ring. Several 1922 engines are equipped with rings ⅛ in. wide, but these rings, so far as our information goes, will exert approximately the same radial stress as that of the 3/16-in. rings formerly employed. These narrow rings, we understand, are used almost entirely in pistons of aluminum alloy, the theory being that the narrow ring

approximately ⅛ in. in width will not wear the grooves as quickly as the 3/16-in. or wider ring.

Everyone in the piston-ring business has been making an effort to produce the best possible piston-ring material for this purpose. Opinions differ somewhat on some details, but generally all ring manufacturers are agreed that there are two main factors to be considered. They are: ability to wear and elastic properties.

Piston-rings operate against the cylinder-wall with a definite pressure at a high rate of speed. A material that will give the best results under these wearing conditions must be used.

The piston-ring acts like a spring, and for that reason must have a high yield-point and a high elastic-coefficient. Steel would be excellent for piston-ring purposes if we did not have the wear factor to contend with. Cast iron in cylinders, pistons and rings has proved to be the ideal metal for all-round purposes. Cast iron wears less than steel in piston-ring operations because it is made up of a steel matrix imbedded with minute particles of pure graphite; this graphite is a natural lubricant. Cast iron, however, ordinarily has very low physical properties, and our problem is to make a spring material with high elastic properties and yet retain the desirable wearing qualities of gray iron.

The effect of the metalloids on the carbon in gray iron is fairly well understood, in that most foundrymen have witnessed the variation in the percentage of the total carbon in iron separated out into combined carbon or graphitic carbon. Great varieties of structure can be produced from gray iron, providing the control of the melting and refining operation is flexible. Very good grades of gray iron have been made by exceptional cupola operation, but there are factors in the operation of the cupola that give it definite limitations.

For the last two years we have been making all of our ring castings by the electric furnace process. The results have exceeded our highest expectations. Our reasons for a change from the cupola process, which has undeniable price advantage, were as follows: Phosphorus and sulphur should be kept to a minimum in gray iron for piston-rings. The cupola adds from 0.02 to 0.04 per cent of sulphur during the melting operation. This is an amount equal to the total sulphur-content of good pig iron. It is difficult to continually obtain an extremely low phosphorus-content in pig iron, but with the electric furnace sulphur and phosphorus are no longer a problem.

The higher the total carbon in gray iron the higher will be the graphitic carbon, which, as previously stated, is very desirable as a lubricant. The form, however, that this graphitic carbon takes determines the strength or weakness of the casting. A high pouring-temperature, together with a perfect control of the silicon and manganese, is necessary to produce a high graphitic separation in finely divided particles. The term "close-grained gray iron" so often used is descriptive of this condition. The pouring temperature of gray iron melted in the electric furnace can be as high as desired, and duplicated exactly day after day.

The effect of oxygen on cast iron has occupied considerable attention during the last few years. For ordinary castings of the usual size, we believe that oxygen plays a very small role. But in casting individual piston-rings that weigh from ½ to 1½ oz. the cooling is so rapid that oxygen in the metal becomes a serious factor. In the electric furnace no blast is used and, if the furnace is properly handled, any oxygen there might be in the charge will be reduced.

The design of piston-rings follows somewhat the general design of springs, and it is necessary to know the physical properties of the material to make the design complete. Standard test-bars of any size such as might be used in steel cannot be used in testing gray iron. The percentage of any total carbon separating into graphite or combined carbon will vary according to the size of the casting and for that reason a true test of the material for calculation purposes must be made on a specimen cast under identical conditions obtaining in a piston-ring casting. For that purpose we use a test-bar ¼ in. wide and 5/32 in. thick. The bar is cast individually, and has a length of approximately 12 in. This bar is identical with the piston-ring except that it is straight and the piston-ring is curved. A very delicate transverse testing-machine is used to run the test. Small increments of loading are registered, and a dial indicator shows the deflection in thousandths of an inch. Test-bars in a transverse test show 23,000-lb. stress before taking any permanent set. The coefficient of elasticity shows upward of 15,000,000 and the transverse breaking-stress runs between 60,000 and 70,000 lb. per sq. in. In spite of the fact that these figures are based on a transverse test, you can see that they are very unusual. With this information it is very easy to arrive at really definite calculations as to the proper ring-tension, thickness, deflection and width.

We take it that your question regarding increasing the tension of rings after manufacture means operations such as heat-treatment or peening. We have never been able to get very far with any sort of heat-treatment on gray iron, and we do not know of anyone who has been successful. Steel is easily annealed, drawn, forged and hardened, but it has a maximum of 0.20 to 0.80 per cent carbon, all of which remains combined. Cast iron has 3.50 per cent carbon with approximately 3.00 per cent in a graphitic form. Free graphite is the principal cause for weakness in gray iron, and it is not susceptible to changes by heat-treatment except possibly to soften the casting further. Our experiences show that heating gray iron generally weakens the structure. We have in no case found any heat-treating process that strengthens it.

Cast iron cannot be successfully forged, drawn or hammered for the same reason that it cannot be heat-treated. The large percentage of graphite makes it granular, and any effort to peen it causes small hair-cracks where the peen strikes. This is not serious in the case of piston-rings peened on the inside, for the reason that the inside of the ring is in compression, and the outside of the ring is in tension while in operation. The hair-cracks are closed because they are on the inner section of the ring. Nevertheless, the hammering process does not and cannot improve the material.

All piston-rings must have an out-of-round shape when uncompressed, so as to fit properly when compressed in the cylinder. Rings are peened to get this out-of-round shape, and for no other purpose. The same is true of heat-treated rings. They are heat-treated so that they can be bent easily to the desired shape. A better process is to put the desired shape in a pattern and cast the ring with the out-of-round condition in it. Why heat or peen a ring if the same results can be obtained in a solid, unstrained material in the casting? The need is to produce a stronger material for piston-rings, and nothing should be done to the ring after casting that will not preserve the original strength or strengthen it more.

To answer your questions more or less in order, we will state first that the material used in our rings is high-grade Northern machine-cast pig iron of various analyses combined so as to produce in the finished product as near as possible the following analysis: graphite carbon, 3.10; combined carbon, 0.45; silicon, 2.75; sulphur, not to exceed 0.055; phosphorus, 0.55; manganese, 0.55. This composition is for rings under 5 in. in diameter. In larger sizes the silicon will run some-

what lower and the sulphur a trifle higher, the latter due to the fact that we use more of our own returns in the large rings.

We maintain a laboratory to analyze carefully all metal received and all coke, limestone, etc., and also analyze samples from each heat. The rings 5 in. and under in diameter should show a Brinell hardness of from 180 to 210; we endeavor to maintain it at 190. Our method of making this test is to use a ½-in. test-bar and after the scale is removed apply a pressure of 3000 kg. on a 10-mm. ball for 15 sec. We make this reading microscopically as to the width of indentation and provide for a check of this reading by determining the depth of the indentation.

Our metal is melted in a cupola and by carefully and accurately combining the grades of iron it is not necessary for us to doctor it to obtain the proper results. We have used the cupola ever since we have been manufacturing piston-rings and have still to be shown wherein an electric furnace will give any better results than we obtain. We pay a premium for the coke we use to get an extremely low sulphur-content, and buy the high-grade limestone and fluorspar for flux. Great care is exercised in the purchase and preparation of our molding sand and all of our patterns are made to the utmost accuracy, the foundry tools and equipment are maintained on the same basis as our machine-shop equipment.

Our rings are cast individually, whether they are of ⅞ or 40-in. diameter, which is our present range of sizes. We have never made rings from pot castings in the 10 years we have been in business. The castings are made in an out-of-round shape. In other words, a piece is inserted in the pattern that is equal in length to the segment we wish to remove for the slot. As this is done by merely slitting the pattern and swaging this section in, it slightly flattens the pattern at that point and you can readily see that, when we remove the corresponding section from the ring casting, our castings will resume a perfectly round shape when the ends are forced together. This is a method originated by ourselves and by it we obtain a ring casting in which there is whatever degree of spring we may require, and also one that, upon being closed to cylinder diameter, resumes a perfectly round shape. This is particularly important as we do not machine the inside of the casting, merely smoothing it upon a stone. This is a very desirable feature as we retain the skin of the casting in this manner, which as you know is the strongest and springiest part of the cast iron.

We have, therefore, in making our castings, provided an absolutely circular ring with a resiliency that will never fail, and whatever pressure we desire by varying the segment in the pattern that is afterwards removed from the casting. By thus producing a casting inherently containing all of the necessary properties such as pressure, truly circular form, and resiliency, it is absolutely unnecessary for us to use any mechanical means of increasing the tension, and we are unalterably opposed to the theory of disturbing the natural position of the molecules of the casting or the ring to produce a property that we obtain by maintaining the casting in its true and natural condition. Our rings, being perfectly natural in their final structure, can be opened to the degree necessary to put them over the piston and closed a great number of times without in any way interfering with the qualities desired. A ring in which a spring is artificially produced will not, we believe, show this same characteristic, as the particles of metal that have been rudely displaced from their natural position cannot permanently provide the same results as one that functions in its natural form.

Our machining processes are built around the peculiar design and construction of our castings and are of course as accurate as is commercially practical. We employ various tools, jigs, fixtures and automatic machines of our own design and believe that this branch of our work is maintained at a very superior standard. The greatest care is used in their inspection. It is an obsession with us to sacrifice whatever need be to maintain or improve the quality of our product.

GAGE-STEEL INVESTIGATION

IN the program for laboratory work to be conducted at the Bureau of Standards the first thing undertaken in the recently projected gage-steel investigation was to determine the reliability of the Amsler wear-test machine. Test discs of S.A.E. No. 1020 steel case-hardened and S.A.E. No. 1090 steel hardened were made up by Pratt & Whitney Co. The case-hardened discs flaked in the machine mentioned and were consequently not suitable for determining its performance. As it is difficult to harden carbon tool-steel uniformly, an oil-hardening steel was made up into discs, hardened and used for preliminary tests of the machine.

As the progress of the wear tests has been rather slow, arrangements were made to get a supply of 1.10-per cent carbon, 1.40-per cent chromium steel for hardening experiments and wear tests and of 0.45-per cent carbon-steel for testing the wear of hard discs against soft. As the chromium-bearing steel is the most universally used gage steel, it is planned to make the most elaborate tests on it.

Some quenching experiments have been made to determine the characteristic curves, cooling power and reproducibility of the common quenching media; this was accomplished by finding calorimetrically the average temperature of a standard nickel cylinder after different times of immersion in the quenching bath. Cooling curves were thus obtained for quenching in water at 30 deg. cent. (86 deg. fahr.) with and without motion of the cylinder, for quenching in oil at 30 deg. cent. (86 deg. fahr.) without motion and with slow and fast motion of the cylinder, for quenching in oil at 10 deg. cent. (50 deg. fahr.), 100 deg. cent. (212 deg. fahr.) and 200 deg. cent. (392 deg. fahr.) without motion of the cylinder, and for cooling in still air.

The heat-treatment of several steels in the form of 4-in. cylinders similar to those recommended by the committee has been varied with the principal object of determining the effect of the rate of heating on the dimensional changes. Some of these cylinders showing large dimensional changes on hardening are being measured for time changes.

The length measurements are being made under the direction of the Gage Section. This section has also prepared an attachment to the millionth comparator to take 4 ± 0.003-in. blocks for measuring the changes on hardening and with time. The attachment includes an oil bath in which the specimens are partially immersed to secure temperature uniformity.

Advantages of Light-Weight Reciprocating Parts

By L. H. Pomeroy[1]

Buffalo Section Paper *Illustrated with* Chart

After pointing out that the general question of weight reduction is no exception to the fallacies that seem to have beset the development of the automobile from its earliest days, the author outlines briefly the problem confronting the automobile designer. The influence of the weight of the reciprocating parts on the chassis in general and the engine in particular is emphasized as being of greater importance than the actual saving in the weight of the parts themselves, it being brought out that the bearing loading due to inertia is really the factor that limits the maximum engine speed. Reference is made to the mathematical investigation by Lanchester in 1907 of the advantages of using materials of high specific-strength and the conclusions arrived at are quoted in full. A tabulation of the specific strengths of various materials used in automotive engineering practice is presented as showing the advantages of aluminum as compared with steel.

The savings in weight that are possible by use of aluminum without any sacrifice of strength are next pointed out. The stiffness of steel and aluminum sheets is compared as one specific instance of weight reduction and this is followed by an extended consideration of aluminum connecting-rods, including an analysis of the loading due to inertia throughout a complete four-stroke cycle, and a comparison of steel and aluminum connecting-rods on a weight basis. The advantages of using aluminum to secure the required stiffness in a connecting-rod because of its low density are emphasized, it being brought out as the result of a mathematical analysis that equal stiffness as compared with steel can be secured in an aluminum connecting-rod with about one-half the weight of the material. An extended comparison of steel and aluminum connecting-rods that have been in service is next presented. The production methods employed for steel connecting-rods are stated as being applicable to aluminum. The advantages of the combination of the aluminum piston and the connecting-rod are pointed out, it being stated that a saving of 15 lb. in this connection as compared with a cast-iron piston and a steel connecting-rod results in an overall saving of about 14 times this amount.

Although automotive engineering science is now arriving at the stage when there are few engineers who claim that weight is advantageous apart from the necessities of strength, the general question of weight reduction is by no means free from the fallacies and false theorizing that seem to have beset the development of the automobile from its earliest days. For example, the average salesman will assert with no little emphasis that it must require more energy to reciprocate a heavy piston than a light one and that the horsepower of the engine is correspondingly affected. This may or may not be true according to the design of the pistons and their relative friction, for it is very easy to conceive of a tight-fitting light-weight piston with many rings offering a greater resistance to motion than a slack-fitting pistion of twice the weight and say one ring. The point is, of course, that if any mass is put into motion and afterward brought to rest as in the case of a piston during its travel, no work is done apart from friction. In other words, the energy put into the piston to start it moving is given up by it during its period of slowing-down to rest. With even greater emphasis it is claimed that the use of light pistons reduces vibration. This again while true as a general proposition is by no means an immediate truism. Most engines run at their best when the inertia-pressure diagram is approximately midway between the compression and expansion lines of the gas-pressure diagram, and it is again easily conceivable that for an engine running at a constant speed increasing the weight of the piston might improve engine smoothness.

The case for light reciprocating parts, however, rests upon grounds which are overwhelmingly more important than the somewhat hair-splitting considerations mentioned above. Before presenting this in detail it is of interest to review briefly the problem before the automobile designer. With a Pierce-Arrow at one end of the scale and a Ford at the other it is only possible to generalize vaguely but there are certain things in common: first, an approximately equal passenger carrying capacity, although the seven-passenger Pierce-Arrow is usually occupied by three or four persons in luxury, while the five-passenger Ford is usually occupied by seven or more in acute discomfort; second, the capacity to traverse any road upon which the wheels can hold; and third, the maintenance with safety of at least the legal limit of speed. These three items can, of course, be supplemented but they cover more or less those chiefly related to road performance.

We have then in an automobile a passenger load supported upon a frame, axles and wheels, together with an engine for propulsive purposes. From the viewpoint of the total weight involved it is obvious that the passenger weight is in accordance with the dictates of birth and diet and not under the control of the designer. The remaining weight is determined chiefly by the selling price of the car, and the problem resolves itself into giving the public the maximum aggregation of virtues that will result in that combination of sales on the one hand and profit on the other, essential to commercial success and stability. This may be differently expressed by saying that the cost of material is the largest single item of the three factors of cost, namely, labor, overhead and material, and that any reduction of the material cost, that is any reduction of the weight and the dimensions, goes hand-in-hand with the reduction of labor and consequently of overhead charges.

As in everything else the more one pays the more one gets or at least expects to get. The man who buys a typical heavy car does so because he associates with such

[1] M.S.A.E.—Consulting engineer, Cleveland.

a car the cardinal virtues of reliability, comfort and first-class road performance and, as it is difficult to obtain these in any other way, he does not resent the relatively high running-costs involved.

It is, therefore, the business of the engineer to fulfill these conditions by applying his knowledge of engineering science and research to the reduction of weight and thereby of running costs without sacrificing one iota of reliability, luxury or longevity, and at the same time to reduce the cost of production so that engineering and economic ideals will progress together.

An examination of the components of an automobile indicates that the bearing surfaces and the weight are closely interrelated and that in orthodox construction at any rate it is possible to build down to a given weight only by reducing the bearing surfaces to the minimum. Throughout an automobile we find this holding true; a few examples are taken at random for purposes of illustration. In the engine the crankshaft dimensions control its own weight and the weight of the bearings supporting it; similarly with the camshaft, pistons, wrist-pin, tappets and other parts. The weight of the clutch is determined by the area of the friction contact; and that of the transmission by the dimensions of the gear teeth and centers, the desired stiffness of the gear shafts and the permissible load upon their bearings, which items in turn decide the dimensions of the case that contains them. The same remarks apply to the universal-joints, the rear-axle bevel and differential gears, the front and rear hubs, the brakes and the steering-gear. The essential difference between the heavy and the light car is in the difference between the factors of bearing wear and the rigidity of construction appropriate to the problem in hand.

The load upon any bearing is due in part to the weight arising from its own dimensions in order that it may be adequately supported and in part to the passenger and body load supported by the chassis as a whole and the power requirements thereof. For approximately the same passenger carrying capacity and body accommodation it is easily possible to have a variation in car weight of from 2400 to 5000 lb. Allowing that the weight of the body fitted to the lighter car is say 700 lb. and that on the heavy car it is say 1100 lb., the chassis weight of the light car becomes 1700 lb. and that of the heavy car 3900 lb., a striking example of how ideals differ in producing two articles professing to do approximately the same job. Actually, of course, they do not do the same job, if the average light car were put to do the work possible with the heavy car, it would give up the ghost very early. The larger shaft dimensions, bearing surfaces and supports in the heavy car have been shown by high-duty experience to be necessary.

While admitting and even claiming this, there have been developments during the past few years in the field of light alloys which profoundly modify the whole problem of automobile design and make it perfectly demonstrable that a wholesale reduction in the weight can be obtained with the same or even higher factors of safety and wear in the bearings, and without the slightest sacrifice of the stiffness of shafts and general chassis construction so essential to a car that is required to meet the most exacting conditions. The object of this paper is to show more particularly the advantages to be derived by attacking one part of this problem only, namely the reduction in the weight of the reciprocating parts and to leave to the imagination the possibilities that can be achieved when this is coupled with the general weight reduction referred to. As will be seen the weight of the reciprocating parts has an influence upon the weight of the chassis in general and the engine in particular, which is vastly more important than the weight saved in the parts themselves.

The extent to which engine dimensions are a function of inertia rather than of gaseous pressures is often overlooked. At very high speeds and part throttle, as when driving downhill, the inertia pressures can easily be much greater than those due to the explosion. On the other hand, when at full throttle and low speed, as when pulling on high gear uphill, the situation is reversed. It becomes of interest and importance, therefore, to obtain some approximate idea of the conditions under which the inertia forces are greater than those due to the explosion.

The capacity of a bearing to withstand wear between the limits of the oil being crushed out of the bearing due on the one hand to heavy pressure and on the other to being evaporated out by the heat generated at high speed, is measured by the product of its mean loading in pounds per square inch and its peripheral velocity in feet per second. This value in good automobile practice should not exceed 16,000. At very low engine speeds the inertia forces are negligible compared to the gaseous pressures, so that for a crankshaft say 2¼ in. in. diameter running at 400 r.p.m., or a peripheral speed of 4.7 ft. per sec., the permissible limit pressure would for a load factor of 16,000 be some 3400 lb. per sq. in., which is very much greater than that actually arising under such conditions. At high speeds, say 2800 r.p.m., with a peripheral speed of 32.9 ft. per sec. the allowable unit pressure would be some 485 lb. per sq. in., a value frequently attained and even exceeded in existing automobile engines.

It may be said that if the bearings of an automobile engine are designed to take care of maximum-speed conditions, low-speed conditions will take care of themselves. As suggested, many automobile engines are now running at speeds that are up to and in some cases above those permissible for bearing reliability and it is not too much to say that bearing loading due to inertia constitutes the real upper limit to commercially possible engine speeds.

The advantages of the use of material of high specific strength, or strength per unit weight, for reciprocating parts were mathematically investigated by Lanchester[2] in 1907, but like many investigations this was somewhat ahead of its time. His generalizations are much more important and applicable to engine design to-day than they were when they were written 14 years ago, and constitute a good example of how pure mathematical reasoning from fundamentals finds a definite application when empirical developments have cleared the way therefor. He pointed out that the limiting speed of engines is determined by the strength of materials and that if similar engines be compared it is possible to predict the relative safe speeds at which they can be run.

The gist of these conclusions is quoted below and the engineer is recommended to study the paper in full.

INFLUENCE OF CHANGES IN THE DENSITY AND STRESS ON THE HORSEPOWER DEVELOPED

We will now revert to the general expression

$$\mathrm{Hp} = (\sigma^{1.5}/\rho^{0.5})\, l^2 \times \text{a constant}$$

and discuss the influence of changes in the physical attributes of the materials employed, i.e. variations of σ and ρ (stress and density).

Translated into ordinary language the expression shows that in similarly designed engines the horsepower varies as the 1.5th power, that is, as the cube

[2] See Proceedings of the Institution of Automobile Engineers, 1907, p 155.

of the square root of the stress, and as the square root of the density of the materials employed.

Now it is evident that the weight of the engine also will depend upon the variables and l, and for the conditions of geometrical similarity the form of this expression is

$$W = \rho l^3 \times \text{a constant}$$

so that the horsepower per unit weight, which is the quantity of most interest to us, will be

$$\text{Hp}/W = [\sigma^{1.5}/(\rho \times \rho^{0.5})] \times (l^2/l^3)$$
$$= [(\sigma/\rho)^{1.5} \div l] \times \text{a constant}$$

Let us denote the quantity σ/ρ by the symbol Φ, and term it the "specific strength" of the material; then we have

$$\text{Hp}/W = \Phi^{1.5}/l$$

We have now the question of weight saving in a nut shell. The above expression shows that to which I have already drawn your attention, the importance of subdividing the power unit by employing a multiplicity of cylinders of individually small size, for we have the horsepower per unit weight inversely as the linear dimension, the latter, l, being the denominator in the above expression. We can also see at once the importance of employing materials of high specific strength; the form of the expression shows that if we can, by employing all-round a higher grade of material, say of 10-per cent greater specific strength, we shall effect a saving of weight of approximately 15 per cent.

Of course, it is not always possible to effect an improvement in the quality of the material in every part of a machine, and it is of considerable interest to us to ascertain where and how the saving in weight is most usefully effected.

WEIGHT SAVING CONSIDERED IN DETAIL

Let us, to fix our ideas, suppose that we have at our command two kinds of material, one of which has just four times the specific strength of the other; and let two carefully designed engines be built to the same specification, one from each kind of material. Now it is evident that, part for part, the one engine can be built one-fourth the weight of the other. There may be some slight difficulties in design, owing to the slenderness of some of the parts, but we can brush this difficulty to one side by supposing the difference of specific strength to be wholly due to a 4 to 1 difference of density, that is, σ remains constant.

So far we have accounted for the Hp/W varying in the direct ratio of Φ only, but the one engine will not only be lighter than the other but it will develop more power, for its reciprocating parts will give rise to less inertia and the revolution speed can be increased. The extent to which the revolution speed can be increased is in the inverse ratio of the square root of the weight of the parts, or in the case in point the revolution speed can be doubled. Thus the horsepower of the lighter engine will become twice as great as that of the heavier one, or its Hp/W will be 4×2; that is, eight times as great, which is $4^{1.5}$ in accordance with the equation.

We thus see that on the former supposition of a 10-per cent improvement in the material, producing approximately a 15-per cent improvement in the power weight factor, 10 per cent of this improvement is due to the direct lightening of the engine and 5 per cent to the increased power derived from the higher revolution speed rendered possible.

It is thus evident that by far the greater importance attaches, relatively speaking, to the quality of the material employed in the pistons and connecting-rods, for these reciprocating parts do not usually exceed 10 per cent of the total weight of the engine, and attention given to this 10 per cent is of as much effect as similar attention devoted to any other 50 per cent of the engine. It is thus found advantageous to adopt the very highest class of material for pistons and connecting-rods. For some years past I have employed a high grade of nickel steel both for the connecting-rod stampings and for the blanks from which the pistons are turned and I believe that the results would justify even more attention still being paid to the reduction of weight in these organs.

A SECONDARY EFFECT

A secondary effect, which must not be lost sight of, results in a saving of weight which is not obvious from a mere inspection of equation for Hp/W.

We have seen that the change in the power-weight factor as due to $\Phi^{1.5}$ takes the form of a saving of weight in the direct ratio of Φ, and in an increase of power in the relation $\Phi^{0.5}$. But we may not want increased power; it is usually some stated power that is required, so that l^2 will require to vary inversely as $\Phi^{0.5}$, that is, l varies as $l/\Phi^{0.25}$. Substituting, we have

$$\text{Hp}/W \alpha\ \Phi^{1.75}$$

under the conditions of stated horsepower, that is to say, hp. = a constant. This may be expressed alternatively by saying that for a given horsepower, for an engine of given number of cylinders, the weight varies inversely as $\Phi^{1.75}$.

The first equation may be written in the form

$$\text{Hp} = \sigma \times \Phi^{0.5} \times l^2 \times \text{a constant}$$

In this form the σ relates to the stress in the working fluid that is the cylinder pressure; taking this as constant we have

$$\text{Hp}\ \alpha\ \Phi^{0.5}\, l^2$$

and when Hp is constant we have

$$\Phi^{0.5} \times l^2 = \text{a constant}$$

or

$$l\ \alpha\ (1/\Phi^{0.25})$$

which gives the same result as before,

$$W\ \alpha\ (1/\Phi^{1.75})$$

We thus see that the saving of weight to be effected by employing high-grade material is even more than we had hitherto concluded, so that a 10 per cent higher specific strength would give about 17.5 per cent, instead of 15 per cent as previously concluded. The earlier figure was perfectly correct so long as the linear dimension of the engine was the constant, instead of the horsepower.

USE OF ALUMINUM

In the searching that has occurred since the facts were recognized for materials in which the tensile-strength was high per unit weight, the manifest advantages of aluminum as compared to steel have been overlooked or not taken seriously.

The specific strength of the various materials commonly used in automotive engineering practice rank as given in Table 1.

From Table 1 it will be seen that the specific strength

TABLE 1—SPECIFIC STRENGTH OF AUTOMOTIVE MATERIALS

	Tensile-Strength, Lb. per Sq. In.	Weight per Cubic Foot, Lb.	Specific Strength
Forged Aluminum	60,000	180	332
0.20-Per Cent Carbon-Steel	80,000	490	163
0.35-Per Cent Carbon-Steel	105,000	490	212
3-Per Cent Nickel-Steel	170,000	490	348
Sand-Cast Heat-Treated Aluminum	30,000	180	161
Chill-Cast Heat-Treated Aluminum	40,000	180	212
Malleable Iron	45,000	480	94
Steel Castings	60,000	480	125
Hard Cast Bronze	35,000	540	65
Cast Manganese	60,000	540	112

of forged aluminum closely approaches that of a 3-per cent heat-treated nickel-steel, while cast aluminum is greatly superior in specific strength to any other cast material in common use. It follows, therefore, that by suitably increasing the dimensions of a part previously made in any of the other materials mentioned, except 3-per cent nickel-steel, it can be made in aluminum to give the same strength but to weigh considerably less. This argument applies directly to cases of pure stress, tension, compression and shearing. There is, however, another very important aspect of the case, which in practice annihilates the superior specific strength of the high-alloy steel, arising from the fact that where compound stresses are involved dimensions per se confer strength.

It is well known that in engineering design generally examples of pure stress are conspicuous by their absence. Even in the simple case of a nut and bolt nominally in tension, it is very doubtful if the nut can be tightened without involving some degree of bending due to the thread being non-axial.

A simple example of compound stress is that of a rectangular beam in which doubling the depth quadruples the load carrying capacity. It may be urged that this applies to all materials, as in truth it does, but a very large portion of the section in the region of the neutral axis of a beam is only lightly stressed compared to that at the top and bottom. This constitutes useless material and it is obvious that if the necessities of design compel useless material to be carried, as they often do, the lower its specific gravity the greater is the weight saving effected. It can, of course, be argued against this that it is possible to design the section of a beam so that this useless material is removed by the processes of manufacture, as in the case of rolled steel sections. Unfortunately, the processes of manufacture to attain the end of eliminating the useless material are limited in scope and expensive in application and this fact constitutes an exceedingly important claim for the engineering and economic advantages of the broadcast use of aluminum in its various forms.

The essence of the technique of weight saving is a study of stress distribution and the design of parts so that the material used is proportional to the load at any point. While it is practically impossible to attain this end, at any rate in most automobile parts, due to the limitations of fabricating processes, the best alternative is to use a material in which the useless portion is of minimum weight.

In automobile design, however, the question of the strength of the various parts is but one aspect of the problem. The majority of parts need consideration from the point of view of stiffness rather than strength.

The history of automobile design is that of the increase in the dimensions of important details to overcome vibration and whippiness. For example, automobile frames are now girders of very great strength, but the strength is entirely secondary to the fact that stiffness is the dominant consideration in the design of a frame so that a closed body can be mounted with a reasonable chance of being able to open or close the doors after 6 months of use. Similarly with axles, transmission cases, crankcases, crankshafts, and other parts, while these were found strong enough in ancient designs they were not stiff enough and their dimensions have been increased.

The strength of a beam (nearly every part of an automobile is a beam in one sense or another) is a function of the square of its depth and its safe tensile-stress, while its stiffness is a function of the cube of its depth and its modulus of elasticity. As this last expression is so intimately connected with the application of aluminum to engineering design it may be worthwhile to explain that the modulus of elasticity of any substance is the ratio of stress to strain within the elastic-limit, the stress being the load per square inch and the strain the extension or compression in inches caused thereby divided by the original length of the piece. In other words, the modulus of elasticity of a material is the load that would double the length of a bar of the material 1 sq. in. in section if the section remained constant. For the common engineering materials, such as steel, cast iron and bronze, the modulii of elasticity are approximately 30,000,000, 17,000,000 and 14,000,000 lb. per sq. in. respectively, while for aluminum it is about 10,500,000 lb. per sq. in. It is of interest to note that the modulus of elasticity is a function of the character of the material rather than of its precise analysis or tensile-strength. Thus low-carbon steel and the nickel-chrome steel-alloys that may vary in tensile-strength by hundreds of per cent do not vary 10 per cent in the modulus of elasticity. Similarly the bronzes and aluminum alloys take their modulus from their basic material and are relatively little affected by the materials that compose the various alloys.

Steel and Aluminum Sheets Compared

With the above in mind it is of interest to compare the stiffness of a sheet of steel with that of ordinary rolled aluminum. For similar supporting means, as in the panel of a door, for example, the deflection due to a load applied at any similarly situated point in each sheet is inversely proportional to the modulus of elasticity and the cube of the thickness. If the thickness of the steel sheet is say 0.04 in. and that of the aluminum 0.06 in., the relative deflections will be as

$$1/[(0.04)^3 \times 30{,}000{,}000] : 1/[(0.06)^3 \times 10{,}500{,}000]$$

or as

$$[(0.06)^3 \times 10{,}500{,}000] \div [(0.04)^3 \times 30{,}000{,}000] = 1.18 : 1$$

The aluminum sheet is, therefore, 18 per cent stiffer than the steel sheet and 50 per cent thicker. As the weight of a steel sheet 0.04 in. thick is approximately 1.6 lb. per sq. ft., while that of an aluminum sheet 0.06 in. thick is approximately 0.9 lb. per sq. ft., it will be seen that this *increase* in stiffness of 18 per cent is accompanied by a decrease in weight of 0.7 lb. per sq. ft., or 43 per cent.

The relative strengths in the above example depend upon the square of the thickness and the ultimate tensile-strength, so that if the steel sheet has an ultimate tensile-strength of 55,000 lb. per sq. in. and the aluminum 25,000 lb. per sq. in., the relative strengths are as 55,000 $\times$ 0.04^2 to 25,000 $\times$ 0.06^2, or as 90 to 88 in favor of the aluminum. With heat-treated aluminum sheet the advantage of aluminum in respect of strength compared to steel would be in the order of 2.4 to 1. This is a perfectly legitimate example of the weight saving that can be obtained by using aluminum in one of its simplest applications to the automotive industry. A survey of fabricating methods and of other metals in general use fails to suggest any other way of obtaining a given desired strength and stiffness with such reduction in weight.

It must be emphasized that by no means the least important aspect of the case for aluminum as a means of obtaining light-weight construction without any sacrifice of strength or stiffness is that practically all engineering design tolerates a vast waste of material in the interest of economical fabrication. For example, a brake-rod that

is threaded at each end has only the strength of the metal at the base of the thread, so that all areas in excess of this are useless. Similarly, a rolled steel beam supporting a floor has a constant cross-section instead of one proportional to the bending-moment applied.

With light-weight alloys the same conditions arise and there is of course in similar designs the same percentage of waste materials. The point, however, is that the absolute dead-weight of useless material in the region of neutral axis is of far less consequence.

The Aluminum Connecting-Rod

The enunciation of these general principles leads to the particular consideration of the aluminum connecting-rod. From the point of view of specific strength, it has been shown that forged aluminum is greatly superior to the steels used in the vast bulk of automotive engine connecting-rods where from the *strength* point of view a steel giving from 80,000 to 90,000 lb. ultimate tensile-strength has proved perfectly satisfactory. There is no doubt that the development of the forged aluminum connecting-rod follows logically from the aluminum piston, to which many makers have been forced to return, and for the same reason, the reduction of internal wear-and-tear in engines by 50 per cent, and the vastly improved performance obtained thereby.

The primary advantage of forged aluminum as a material for high-duty connecting-rods in high-speed internal-combustion engines arises from the fact that the chief cause of bearing wear and failure is the loading imposed upon the crankshaft and connecting-rod bearings due to the inertia of the moving parts.

The loading on the connecting-rod big-end bearings is composed of two parts; (*a*) that due to the fluid, the gaseous mixture in the cylinder, pressures during compression and expansion, and (*b*) that due to the inertia forces arising solely from the mass of the moving parts, the piston and the connecting-rod.

If the four strokes of the conventional four-stroke cycle are examined the following will be apparent:

(1) At the beginning of the induction stroke, the loading of the big-end and adjacent crankshaft main bearings is due to piston and connecting-rod inertia only and acts on the inner side of the crankpin, or that nearest the axis of the crankshaft
(2) Slightly before the middle of the induction stroke the piston inertia forces vanish but the full inertia of the connecting-rod big-end is exerted on the inner side of the crankpin
(3) At the end of the induction stroke the full effect of piston and connecting-rod inertia still is exerted on the inner side of the crankpin
(4) At the beginning of the induction stroke the full effects of piston and connecting-rod inertia still are exerted on the inner side of the crankpin
(5) At the middle of the compression stroke the piston inertia vanishes and the loading on crankpin is due to connecting-rod big-end inertia, the direction still being toward the inner side of the crankpin but slightly modified by the fluid pressure
(6) At the end of the compression stroke the loading on the crankpin is the difference between the fluid loading due to compression and the inertia pressure of piston and connecting-rod. Hence at the moment before ignition the crankpin is subject to its smallest loading at least at speeds of 1000 r.p.m.
(7) At the beginning of the explosion stroke the loading on the crankpin is due to the difference between the explosion pressure and the inertia pressure of the piston and the connecting-rod. At high speeds and part throttle these may also neutralize each other
(8) At the middle of the explosion stroke the preponderating load is due to the fluid pressure but the centrifugal loading due to big-end inertia remains
(9) At the end of the explosion stroke the loading of the crankpin is due to the sum of the inertia pressures due to the piston and the connecting-rod plus that due to the fluid pressure and is exerted also on the inner side of the crankpin
(10) At the beginning of the exhaust stroke the loading is on the inner side of the crankpin and due to piston and connecting-rod inertia
(11) At the middle of the exhaust stroke the loading is on the inner side of crankpin and due to the big end of the connecting-rod inertia
(12) At the end of the exhaust stroke the loading is on the inner side of the crankpin due to piston and connecting-rod inertia

With regard to the 12 positions of the crankpin mentioned, it will be seen that in three only, namely, the end of the compression stroke and the beginning and the middle of the explosion stroke, do the fluid pressures in any appreciable way counteract the effect of the inertia pressures. It will be seen also that the pressure on the inside of the crankpin bearing due to the centrifugal action of the big end of the connecting-rod is always present. This action is approximately that due to the weight of the big end of the connecting-rod, the weight obtained by placing the big end of the rod on a scale-pan, while the small end is freely supported in space. It should be noted also that at the top and the bottom of the stroke, the inertia pressure on the inner side of the crankpin is that arising from the whole mass concerned, or the complete piston *plus* the whole connecting-rod.

In general the inertia effect of the connecting-rod may be considered as if the weight of the big end as previously described is concentrated to the crankpin while the difference between this weight and that of the whole connecting-rod, or the weight of the small end, is concentrated at the wrist-pin. For example, a steel connecting-rod for a 3½-in. bore engine made as light as practicable weighs about 3.50 lb., of which 2.75 lb. can be reckoned as rotating mass and the remaining 0.75 lb. as reciprocating mass. In aluminum this could be reduced to 2 lb., of which about 1.5 lb. would be rotating and 0.5 lb. reciprocating mass.

A cast-iron piston for a 3.5-in. cylinder bore weighs about 2.25 lb. complete.

The effect of using an aluminum connecting-rod would in such a case reduce the big-end loading due to inertia, neglecting connecting-rod angularity, in the ratio of 2.75 to 1.50 at the middle of the stroke, where the piston inertia forces vanish, and in the ratio of 5.75 to 4.25 at the ends of the stroke, an advantage in the reduction of the load factor varying from 40 to 26 per cent, or a mean reduction of some 33 per cent.

The advantage thus obtained can be utilized by

(1) Reducing the width of the bearings by 33 per cent, which in turn reduces the overall length and the total weight of the engine
(2) Reducing the gear-ratio and running the engine at a higher speed, thus obtaining a better performance with the same factor of bearing safety
(3) Improving this factor in engines that are unduly supplied with bearing surface

In brief, the use of aluminum for connecting-rods affords a ready means of making great overall economies

in a new design and of allowing a considerable development of existing designs.

Connecting-Rod Design

The greatest difficulty in connecting-rod design is to give adequate support to the babbitt or other material in direct contact with the crankpin without an undue increase of the weight. This is not a matter of strength of the supporting means, either steel or aluminum, but of securing stiffness. In this connection aluminum is particularly valuable owing to its low density. For example, a connecting-rod to suit a 2-in. diameter crankpin must be bored out to at least a $2\frac{1}{8}$ in. diameter, leaving 1/16 in. for babbitt. The mean thickness of the metal surrounding the babbitt in steel should be at least $\frac{1}{4}$ in., neglecting big-end bolt bosses.

The mass of such a big end in steel is, therefore, proportional, the difference between the squares of the outside and the inside diameters multiplied by the density, or

$$[(2.625)^2 - (2.125)^2] \times 0.28 = 0.7$$

The stiffness for the same internal diameter is approximately proportional to the cube of the mean thickness times the modulus of elasticity or

$$0.25^3 \times 30{,}000{,}000 = 468{,}750$$

Since the stiffness of a part is proportional to its modulus of elasticity, other things being equal, and as the modulus of elasticity of aluminum is 10,000,000, while that of steel is 30,000,000, it follows that to obtain the same stiffness of the big end in aluminum as in steel the thickness must be increased accordingly.

$$\sqrt[3]{(30{,}000{,}000 \div 10{,}000{,}000)} = 1.44$$

The equivalent thickness, therefore, in the above example becomes

$$0.25 \times 1.44 = 0.36$$

From this the relative weight of the aluminum big-end is as before proportional to the difference of the squares of the outside and the inside diameters multiplied by the density, or

$$[(2.845)^2 - (2.125)^2] \times 0.1 = 0.36$$

Thus it will be seen that the same stiffness can be obtained in an aluminum rod for about one-half the weight of material required in a steel construction.

Apart from the amount of metal required to give the desired stiffness of bearing support, the question arises as to the number of bolts for securing the big-end bearing-cap. As a rule four bolts make a much better job than two and incidentally need be no heavier.

It is important to provide plenty of bearing surface between the cap and its abutment on the connecting-rod. The proportions of the small end of the connecting-rod are dependent upon the vagaries of the designer of the wrist-pin, but it should be kept in mind that the weakest part of the wrist-pin in a vertical engine is at the top of the rod, through which an oil-hole is generally drilled. The metal at this point should be $2\frac{1}{2}$ to 3 times as thick as at the sides of the wrist-pin.

Coming now to the proportions of the shank of the connecting-rod, namely that part between the big and small ends, the region is entered in which much high-class mathematics may be applied. This would be justifiable if engineers had any complete knowledge of the distribution of the stress in a connecting-rod; as such knowledge is only now being acquired in respect of the very simplest structures, experience is still the best guide. In the nature of things it is highly probable that stress distribution is more uniform in a ductile metal such as forged aluminum than in less ductile metals such as nickel-chrome steel.

In the present state of knowledge it appears to be perfectly safe to make the section of an aluminum rod that replaces a reliable steel rod such that the section in the aluminum rod is similar to that in the steel rod and of twice the area. All designers will realize the number of exceptions there may be to this rule and the desirability of consultation with the prospective suppliers of the aluminum connecting-rod forgings.

The effect of aluminum connecting-rods on crankshaft bearing design is important. Many engine builders use counterbalanced crankshafts to reduce main-bearing wear, particularly on the middle main-bearing. There are, however, certain distinct objections to this practice. In the first place, a counterbalance crankshaft is heavy and expensive, and in the second place it introduces a distinct liability to torsional periodicity, particularly in six-cylinder engines.

The necessity for such crankshafts arose from the bearing wear that was due in turn to heavy pistons and connecting-rods. The use of aluminum rods reduces very considerably the crankshaft skipping-rope action which causes bearing wear. It is safe to say that in combination with aluminum pistons as well, counterbalanced crankshafts are unwarranted and disadvantageous.

Comparison of Steel and Aluminum Connecting-Rods in Practice

An interesting example of the truth of the foregoing remarks is obtained by comparing the characteristics of a steel connecting-rod taken from one of the best four-cylinder engines produced and of an aluminum rod that has done many thousands of miles under most exacting conditions without a suspicion of failure. The only criticism that can be urged against the steel connecting-rod under discussion is that it is too light, particularly in respect of the metal supporting the babbitted shell in the big end. The steel connecting-rod is from an engine of $3\frac{3}{8}$-in. bore and 5-in. stroke; the aluminum rod is from an engine of $4\frac{1}{8}$-in. bore and $4\frac{1}{4}$-in. stroke.

The detail dimensions and weights are as follows:

	Steel	*Aluminum*
Length betweeen Centers, in.	$12\frac{1}{8}$	$11\frac{5}{8}$
Diameter of Big-End Bearing, in.	$1\frac{7}{8}$	2
Length of Big-End Bearing, in.	$2\frac{1}{4}$	$2\frac{1}{4}$
Diameter of Wrist-Pin Bearing, in.	$\frac{7}{8}$	$1\frac{1}{8}$
Length of Wrist-Pin Bearing, in.	$1\frac{1}{4}$	$1\frac{5}{8}$
Total Weight of Rod, lb.	2.900	2.140
Weight of Big End, lb.	2.340	1.690
Weight of Small End, lb.	0.560	0.450
Weight of Piston[3], including Wrist-Pin and Piston-Rings[4], lb.	1,206	2.040
Total Reciprocating Weight, lb.	1.766	2.490
Total Reciprocating Mass, lb.	2.340	1.690

[3]Piston is made of aluminum in each case.

[4]The piston used with the steel connecting-rod has three piston-rings, while that used with the aluminum connecting-rod has four.

Now as previously stated the loading of the crankpin bearing due to the inertia forces is ascribable in part to the centrifugal effects of the rotating mass of the big end of the connecting-rod itself and in part to the reciprocating inertia-effects of the piston and the connecting-rod small-end. These latter apply at the top and the bottom of the stroke only, while the former acts continuously. The mean loading, therefore, is that due to the rotating mass of the big end plus *half* that due to the reciprocating masses, as these are fully manifested only at each end of the stroke and vanish about the middle thereof.

The actual pressures manifested are directly proportional to the weight of the parts in question, the square of the number of revolutions per minute and the stroke. In comparing the two connecting-rods, however, the speed of the engine may be neglected, as the comparison be-

tween the two rods at any engine speed will hold at any other. We have then the average loading of crankpin proportional to the stroke multiplied by the sum of one-half the weight of the reciprocating parts and the weight of the rotating parts.

For the steel rod this becomes

$$5\,[(1.766 \div 2) + 2.340] = 16.100$$

while for the aluminum rod the loading is proportional to

$$4.25\,[(2.49 \div 2) + 1.69] = 12.50$$

The advantage obtained in reduction of big-end bearing pressures by the use of aluminum connecting-rods is thus clearly manifest, especially when it is noted that in each case aluminum pistons of similar design were used. The argument, however, goes much further than this, as the engine in which the steel rods are fitted is of $3\frac{3}{8}$-in. bore and 5-in. stroke, while that with the aluminum rods is of $4\frac{1}{8}$-in. bore and $4\frac{1}{4}$-in. stroke.

The final result may be computed in terms of cylinder capacity or of piston area. In the former the inertia effects of the steel rod are proportional to $16.100 \div 45 = 0.368$, while for the aluminum rod this "figure of merit" becomes $12.500 \div 55 = 0.228$. Figured on the basis of piston area, the comparison becomes $16.10 \div 8.90 = 1.81$ for the steel rod and $12.50 \div 13.30 = 0.94$ for the aluminum rod.

These figures are sufficiently striking to justify attention, and would be even more remarkable if the engine with steel connecting-rods were designed to reduce the secondary unbalanced forces to the same extent by having the same ratio of connecting-rod length to crank-throw as that in which the aluminum rods are used. This inherent advantage of the short-stroke engine can, however, be thrown in and still leave the argument for the aluminum connecting-rod in its above convincing state.

Summing up, as between two engines, one $3\frac{3}{8} \times 5$ in. and the other $4\frac{1}{8} \times 4\frac{1}{4}$ in., each using aluminum pistons and both of really modern design, the inertia effects that determine the capacity of the engine to resist wear-and-tear of the bearings are reduced by 38 or 48 per cent by the use of aluminum connecting-rods, depending upon whether the cylinder capacity or the piston area is used as a basis for comparison. If it is argued that in the case of the engine with steel rods the wear-and-tear is satisfactory from the user's point of view, the figures then show clearly the possibilities of reducing the size of the bearings and the overall length of the engine, and of the manufacturing economies in respect to the total weight of material required for a given result.

In addition to the above analysis of bearing loading it may be of interest to compare the strength of the aluminum and the steel rods. Considered as a strut, the strength of a connecting-rod is directly proportional to the moment of inertia of its cross-section at the point of maximum stress (which is approximately midway between the ends) and the modulus of elasticity of the material, and inversely proportional to the square of its length. The student will recognize the above as the basis of Euler's formula, which is used as a ready means of comparison for the reason that the relation of the length of automobile connecting-rods to their cross-section does not vary greatly in practice. The moments of inertia of the cross-sections of the connecting-rods are 0.024 and 0.090 for the steel and the aluminum rods respectively.

The relative load-carrying capacity is then $(0.024 \times 30{,}000{,}000) \div (12.125)^2 = 4900$ for the steel connecting-rod and $(0.090 \times 10{,}000{,}000) \div (11.625)^2 = 6650$ for the aluminum connecting-rod, or the relative strengths of the steel and aluminum rods are as 1 to 1.36, the relative piston areas and total explosion pressures being as 1 to 1.5. On this reckoning it will be seen that the aluminum rod is not proportionally so strong as the steel rod. On the other hand, the aluminum rod in question has been subject to most drastic running without a suspicion of failure and from all practical points of view is well up to its job.

The truth is that the loading of a connecting-rod is so complex that it is difficult to reduce it to calculation. If engines were run at full throttle continuously at low speeds, the explosion pressure would be the determinant of the design. Just as the speed increases to that at which engines normally run, so do the inertia effects cancel out those of the fluid pressure, while at the very partial throttle required to run an automobile at say 30 m. p. h. the inertia effects completely overwhelm those of the explosion. Further, the compressive stresses set up by the explosion are not nearly so harmful as the alternating stress induced by inertia, so that the above discussion in respect of the explosion pressure is of not much more than academic interest.

In practice it is difficult or impossible to stamp steel rods of sufficiently light section, and subsequent machining is necessary to obtain the best results in respect to strength and lightness. The steel rod in fact suffers from excessive strength and insufficient stiffness. Even if machining is resorted to in order to reduce the weight of the rod, the extent to which this can be done is practically limited to the shank of the rod and the resultant effect is small. For example, on the steel rod in question the reduction of the average section of the rod to 1/16-in. thickness instead of the average 7/64 in. aimed at in forging would reduce the weight by some 3 oz. only, about 6 per cent, an insignificant result compared to that easily attainable by the use of forged aluminum.

Manufacturing Consideration

The general methods of manufacture applied to steel connecting-rods are equally applicable to aluminum. In aluminum rods machining the shank to reduce the weight may be dispensed with, as the consequent reduction of the weight is negligible. Further, there is no necessity for bushing the small end of the rod, although such bushing may be desirable in the case of small-bore engines where the wrist-pin is necessarily short.

Similarly, with aluminum rods the same babbitted shells may be used as with steel rods, although this practice is regarded as mechanically deficient with either steel or aluminum rods. The use of the babbitted shell necessitates increasing the total weight of the big end to compensate for the additional diameter of the big-end bore necessitated by the shell. More important still, the heat generated by big-end friction *and* that conducted down the rod from the hot region near the piston, has to be dissipated through two oil-films, that between the babbitted shell and the crankpin itself and that between the outside of the babbitted shell and the connecting-rod big-end proper. As the whole object of a bearing is to dissipate readily the heat generated by friction, it is difficult to see why its conductivity should be reduced by 50 per cent.

It may be argued that the advantage of the babbitted shell lies in its capacity for ready replacement. While this may be true, the percentage of bearing failures when babbitted shells are not used is so small as to make it more satisfactory and economical to replace the whole connecting-rod. As in many other instances in automobile design, the provision made for replacement makes the replacement necessary.

On the above grounds the use of direct-babbitted con-

necting-rods is strongly urged. From the production point of view there is no more difficulty than in babbitting a bronze shell and there is the economy obtained by dispensing with the shell. Successful methods of babbitting aluminum connecting-rods have been developed from the points of view of a complete technical solution of the problem and of rapid economical production. The results of these methods are such that the babbitt in a connecting-rod can be removed only by melting or laborious chipping. There is a definite metallic fusion between the aluminum and the babbitt that it is practically impossible to obtain with steel or bronze.

In the foregoing it has been taken for granted that the virtues of the aluminum piston are generally recognized by engineers; however much they may differ as to whether these virtues are offset by disadvantages. The renaissance of the aluminum piston is beyond doubt, so that it is fair to assume that the aluminum piston has been found to possess a number of advantages. It may not be out of place to state that this is due to the following:

(1) The elimination of piston slap by the use of pistons capable of distorting under high temperature
(2) The reduction of wear by carefully finishing the surface of the cylinder bore and the development of piston alloys of a hardness comparable to that of cast iron

The combination of aluminum piston and connecting-rod allows for a weight reduction of at least 40 per cent in these parts compared with ferrous metals as now employed. The consequences are

(1) That the engine may be speeded up with safety in the ratio of $\sqrt{(100 \div 60)}$, or 30 per cent with the same bearing areas
(2) The bearing areas may be reduced by from 30 to 40 per cent and the engine run at the same speed
(3) Combinations of (1) and (2)

Working along these lines, the author has recently designed an engine with $3\frac{1}{4}$ x 5-in. cylinders in which the bearing load factor at 3200 r.p.m. does not exceed 14,000 with big-end bearings $1\frac{1}{2}$ in. between the crank webs and $1\frac{1}{8}$ in. in net width. With cast-iron pistons and steel rods the corresponding net width of big-end bearing would be about $1\frac{5}{8}$ in. The saving in the overall length on a six-cylinder engine is, therefore, some 3 in. in respect of big ends alone, together with further saving of the same amount in the main bearings.

The saving in engine weight arising from this reduction of bearing surface is about 15 per cent, while the available engine speed and torque are all that is required for a car of the medium large type. In other words, a 240-cu. in. engine thus designed with a $4\frac{1}{4}$ to 1 gear-ratio is capable of doing the work of the average 300-cu. in. engine with a 4 to 1 gear-ratio.

The disposition of weight in an automobile chassis is roughly as follows:

	Per Cent
Engine	25
Frame	10
Wheels and Tires	12
Clutch and Transmission	10
Torque Member, Universal-Joints, etc.	2
Rear Axle	12
Front Axle	3
Radiator and Hood	4
Springs	8
Electric Equipment	6
Steering-Gear	2
Gasoline Tank	1
Miscellaneous	5

Of these approximately 25 per cent, notably the frame, wheels and tires, is substantially independent of the chassis weight in that they are dominated in design by body considerations. Treating the engine as a separate unit weighing 25 per cent of the total chassis, we are left with 50 per cent of the chassis weight varying in some degree with the engine torque. The multiplicity of considerations underlying the design of these parts precludes any definite statement of the extent of this variation, but it is probably safe to say that for equal rigidity of construction the net saving is proportional to the square root of the ratio of the torque under consideration.

Thus the weight of the transmission of a car with a 240-cu. in. engine compared to that of a 300-cu. in. engine, both developing the same brake mean effective pressure, would be as $240/300 = 0.89$, indicating an 11-per cent saving in this respect. Summing up, we have a weight reduction of 15 per cent in the engine itself, or some 3.75 per cent of the whole chassis, together with say an 11-per cent reduction in the weight of 50 per cent of the chassis, or 5.5 per cent of the whole; in all some 9 per cent arising indirectly from the use of aluminum connecting-rods and pistons. In the case of a chassis weighing 2400 lb. the net result is, on the above reasoning, a saving of 216 lb. The weight of the cast-iron piston and steel connecting-rod in a six-cylinder 300-cu. in. engine would approximate 36 lb., while their aluminum counterparts would weigh some 21 lb. Thus a saving of 15 lb. in pistons and rods results in an overall saving of about 14 times this amount.

To forestall criticism, no one is more aware than the author is of the vagueness of this estimate, due to the vast number of factors that enter into the problem. On the other hand, there is no doubt of the truth of the general proposition as to the enormous benefits to be derived by reducing the weight of reciprocating parts by the use of light-weight alloys. The limitations of this paper unfortunately preclude any discussion of the potentialities that lie in the application of these materials throughout the chassis. The fact that extended experience has shown them structurally suitable for the hardest worked parts of the whole chassis indicates the confidence with which they may be applied elsewhere.

THE DISCUSSION

DAVID FERGUSSON:—Mr. Pomeroy's paper is so convincing that it is somewhat difficult to give good reasons for not following his advice. However, there are a few points that I would like to call attention to. In the table giving the specific strength of various automobile materials, the figures of most consequence are those of the elastic-limits of these materials, rather than those of the ultimate tensile-strengths. If this be conceded, it changes the position of the forged aluminum materially. I believe I am right in stating that the elastic-limit of forged aluminum is about 25,000 lb. per sq. in. Its specific strength in relation to its elastic-limit is therefore 133. The elastic-limit of 0.35-per cent carbon-steel heat-treated to give 105,000-lb. tensile-strength will be about 80,000 lb. per sq. in., giving a specific strength of 163, or nearly 25 per cent greater than that of forged aluminum. The elastic-limit of 3-per cent nickel steel heat-treated to give a tensile-strength of 170,000 lb. per sq. in. will be about 130,000 lb. per sq. in., giving a specific strength of 263 or double that of forged aluminum.

A doubtful point in connection with this comparatively new material is its life or endurance. Mr. Pomeroy has had personal experience with this in service, which is the

real test, yet a test I had made about 3 years ago in a Stanton fatigue-testing machine gave very poor results, the specimen failing after 1092 blows of a weight falling 1 in. Common screw-stock of about 0.20-per cent carbon-steel stood 6000 blows. Forged aluminum, no doubt, has been improved since this test was conducted.

The hardness of forged aluminum is I believe only about 100 Brinell, compared with 230 for heat-treated 0.40-per cent carbon-steel. If this is so, is there not trouble due to the metal peening-out? This would result in the small end of the connecting-rod enlarging on the piston-pin if no bearing bushing were used, or in the bushing becoming loose, if one were used. Is there any trouble due to the big-end bolt-heads peening their way into the softer aluminum? Is it necessary to use a large steel washer between the connecting-rod cap and the nuts on the big-end bolts?

Is there not some trouble from the greater expansion of the small and big ends of the aluminum rod, giving these a greater clearance than desirable and so causing a knock? This is one of the troubles I have had with aluminum pistons in which the piston-pin floated in the piston. Unless these were assembled very tight when cold, there would be a knock when the piston warmed-up.

Is not the cost of the aluminum forging somewhat excessive? When I looked into this matter three years ago I found that the cost was so great that it would pay to use steel and machine the rod all over, as the saving in weight would then be very little, the only large saving being in the big end, as I considered, perhaps wrongly, that the cross-section of the rod should be three times that of the 0.35-per cent carbon-steel that is the material I have used on all medium-speed engines, the stiffness being as great as that of the higher-priced alloy-steels. The elastic-limit of this steel is three times that of the aluminum and the modulus of elasticity is about three times that of aluminum, while the specific weight of the aluminum is less than one-third that of steel. In making the comparison, I, of course, figured on a bronze bushing in both the large and small ends of the aluminum connecting-rod.

The saving in the length of Mr. Pomeroy's engine, due to the use of aluminum pistons and connecting-rods, is certainly very interesting. However, I have found that the length of a six-cylinder engine is largely controlled by the diameter of the cylinder bore; the wall thickness; and the space for water between the cylinder barrels, which I consider a necessity. The last named cannot be less than 1/4 in. and should be more to satisfy foundry requirements. The diameter of the crankshaft must be so large to avoid excessive torsional vibration that the length of the bearings that the above conditions admit of are usually ample for all medium-speed engines.

I would like to hear more of the type of aluminum piston Mr. Pomeroy has had most success with, including how he avoids piston slap when cold and scoring when hot. I believe that there is a great future for the use of forged aluminum in automobile construction. Mr. Pomeroy has done much to show the way.

L. H. POMEROY:—Mr. Fergusson, with characteristic thoroughness, puts up the contra side of the aluminum versus steel argument. I cannot, however, let his figures on specific strength in terms of elastic-limit pass without comment. In the first place, the elastic-limit of any material is most difficult to ascertain. In fact, the only physical properties that can be determined with anything like accuracy are the ultimate stress and the elongation. It is upon the former of these that the vast bulk of safety factors are based. Without going into this very vexed question, let us see what happens if, instead of taking the elastic-limit as a basis for determining the specific strength, we take another quantity that is related thereto but more easily measured, namely the yield-point.

It is well known that by suitable heat-treatment carbon and alloy-steels can be made to give a very high ratio of yield-point to ultimate tensile-strength at the expense of elongation, but such high ratio and consequent brittleness by no means make the material more suitable for practical purposes. In other words, experience shows that elongation is a necessary characteristic of most materials of construction and that it must be obtained even at the sacrifice of a high yield-point. This in itself to a large extent invalidates Mr. Fergusson's basis of comparison unless such basis predicates the same elongation as may be obtained with wrought aluminum. The yield-point of a good wrought aluminum alloy with an elongation of 20 per cent is approximately 35,000 lb. per sq. in. with an ultimate stress of 60,000 lb. The specific strength in terms of the yield-point becomes therefore the yield stress divided by the weight per cubic foot, or $35,000 \div 189 = 185$. The physical characteristics of S.A.E. No. 1035 steel, having a carbon-content of 0.35 per cent, as given in the S.A.E. HANDBOOK show that when this material is treated to give a 20-per cent elongation it has an ultimate stress of 95,500 lb. per sq. in. and a yield-point of 64,500 lb., the specific strength in terms of the yield-point being $64,500 \div 490 = 132$.

Similarly, S.A.E. No. 2330 steel, which is a 3-per cent nickel 0.30-per cent carbon-steel susceptible of being heat-treated to give 170,000-lb. ultimate stress, possesses only an elongation of some 11.5 per cent in this condition. When treated to possess an elongation of 20 per cent the ultimate stress becomes 104,000 lb. per sq. in. and the yield-point 77,000 lb., the specific strength in terms of the yield-point being $77,000 \div 490 = 157$. These figures show then that the specific strengths of wrought aluminum, 0.35-per cent carbon-steel and 3-per cent nickel 0.30-per cent carbon-steel, all with an elongation of 20 per cent, are 185, 132 and 157 respectively, instead of having values of 133, 163 and 263 as given by Mr. Fergusson.

With respect to endurance or resistance to repeated stress, one cannot of course expect all the poor results to be found with steel only. I would only remark that there are few tests that seem to have provoked more argument as to their value than fatigue tests in general. In actual practice automobile engine connecting-rods can be made in aluminum with from 55 to 60 per cent of the weight of a steel connecting-rod, including bolts, babbitt, etc., and have stood up under the most strenuous conditions. In the aluminum car I have designed we run the engine at speeds of over 3000 r.p.m. with impunity and in a collective mileage on four cars of nearly 80,000 miles and on one car of some 40,000 miles there has not been a symptom of failure. Forty thousand miles with a gear-ratio of 4.25 to 1 is approximately 1780 hr. running at 1000 r.p.m., or $1780 \times 60 \times 1000 = 107,000,000$ revolutions, or 214,000,000 strokes. Allowing three stress reversals per cycle, this becomes over 150,000,000 stress reversals.

Some fatigue experiments made in a fatigue-testing machine consisting of a motor-driven crank and weighted cross-head may be of interest. At 1500 r.p.m. the wrought aluminum rod gave a life of 353 hr. when the crosshead itself broke, whereas the steel rod failed in one case after 25 hr. and in another after 45 hr. of running under identical conditions. The steel rod was of

smaller section but about double the weight of the aluminum rod.

So far as peening-out is concerned no trouble has been experienced, nor should there be any if sufficient metal is used around the small-end bearing. With steel rods, of course, a bronze bushing that does not peen-out is universally used, so that the comparison between the Brinell hardness of wrought aluminum and of 0.40-per cent carbon-steel is hardly appropriate.

Steel washers are certainly desirable and in fact necessary to avoid trouble arising from the nut of the connecting-rod bolt or lock-washer cutting the aluminum when being tightened.

The difference in expansion of aluminum in contact with steel is about 0.001 in. per in. per 100 deg. fahr. Given a good initial fitting of the wrist-pin and adequate lubrication, no trouble is experienced, although doubtless these conditions are more important than with a steel rod unless the aluminum rod is bushed, in which case the requirements are identical. It is not the least of the advantages of the aluminum rod that the usual bronze bushing in the small end may be eliminated.

The cost of aluminum rods nowadays competes with an unmachined steel rod if the big end of the aluminum rod is direct-babbitted, and is much less than that of a steel rod machined all over.

I think that Mr. Fergusson's remarks on overall engine length apply primarily to a T-head engine. Admitting his premises, there is no reason why the bore cannot be reduced, which shortens the engine and reduces weight to a greater extent than it is increased by the longer stroke required for a given cylinder capacity.

The aluminum pistons to which Mr. Fergusson refers are of the split-skirt type made by the United States Aluminum Co. These pistons are characterized by the nature of the piston skirt, which is split to allow for expansion, and by the section of the skirt which is designed to allow deformation to take place without causing the portion of the skirt that is in contact with the cylinder to go out-of-round.

A further important feature is the discovery of a process for making these pistons up to 150 Brinell hardness, which has a marked effect upon their resistance to wear. In the engine previously mentioned these pistons are put up with 0.004-in. clearance for a 4⅛-in. bore and no trouble has been experienced from seizure or slap.

The successful aluminum piston, like the successful aluminum connecting-rod, cannot, however, be designed blindly. There is a definite technique of construction that has to be observed and those who imagine they can substitute aluminum for steel or cast iron without modification had better not consider the matter further.

MR. FERGUSSON:—Have you any trouble with scoring of the cylinder?

MR. POMEROY:—Not that I know of.

E. H. SHERBONDY:—Is the constant you give for loads of 16,000 Ricardo's or your own? And how was it arrived at?

MR. POMEROY:—The constant was arrived at empirically by Mr. Ricardo, and is in conformity with my own experience. It is the average loading or pressure taken on the crankpin bearing.

OTTO M. BURKHARDT:—I notice that there was rather a sharp line of demarkation between Mr. Fergusson's and Mr. Pomeroy's figures. They represent, so to speak, two different schools of design. Mr. Pomeroy is basing his calculations entirely on the tensile-strength and Mr. Fergusson is basing his calculations on the elastic-limit. As Mr. Pomeroy says, the elastic-limit is rather an indefinite figure, whereas the tensile-strength is well defined and can be obtained, even with crude testing-machines. All fatigue tests that I know of have invariably been formulated on the basis of tensile-strength. During some very interesting tests made at the University of Illinois, it was found that the formulation of the results can be made to better advantage on the basis of the Brinell hardness. There is a fairly definite relation between the Brinell hardness and the tensile-strength of heat-treated steel. This relation has been established by John Miller, the metallurgist of the Pierce-Arrow Motor Car Co., and is represented approximately by

$$\text{Tensile-Strength} = 500 \times \text{Brinell Hardness}$$

No similar relation can be given for the elastic-limit but a very similar relation can be given for the yield-point. It is, according to Mr. Miller,

$$\text{Yield-Point} = 550 \times (\text{Brinell Hardness} - 75)$$

From this it follows that, when factors of safety are based on the yield-point, a happy compromise can be obtained between the two schools here represented. Mr. Pomeroy has chosen the tensile-strength for the simple reason that there is no well-defined elastic-limit in the case of aluminum. Mr. Fergusson has chosen the elastic-limit because this can, through patient research, be found for steels, and Mr. Fergusson, I take it, is a sponsor for the use of steel. In the calculations that I have carried out I have found it most satisfactory to base the factors of safety on the yield-point where infrequent shocks are under consideration. Where fatigue is under consideration, it is advantageous to deal with the tensile-strength. I have analyzed somewhat further the relative merits of the metals here under consideration. If we denote the tensile-strength of ferrous metals by T_f and the tensile-strength of aluminum by T_a, the ratio between the two is

$$T_f/T_a = K$$

This relation indicates that ferrous metals are K times as strong as aluminum, although K may well be smaller than unity.

If we further take into consideration the specific gravity of the two metals, we have another factor that rather expresses the inverse of the previous factor, namely the density of aluminum relative to ferrous

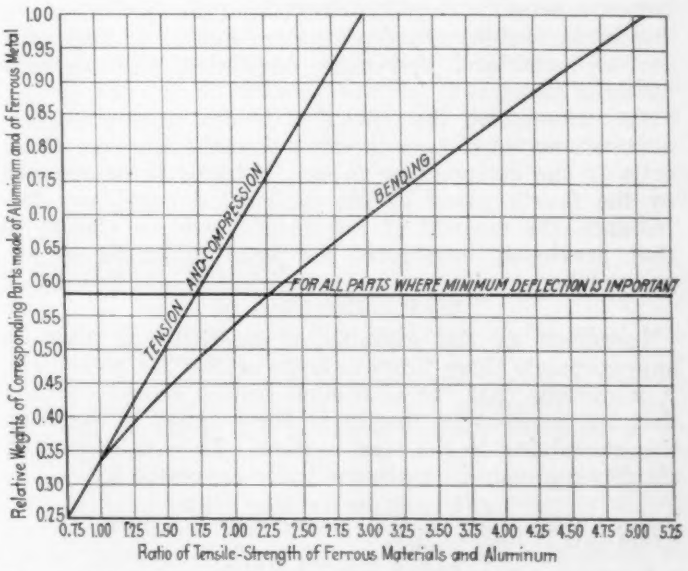

FIG. 1—CHART SHOWING THE RELATION BETWEEN THE RELATIVE WEIGHT OF CORRESPONDING PARTS MADE OF ALUMINUM AND FERROUS METALS AND THE RATIO OF TENSILE-STRENGTH OF FERROUS METALS AND ALUMINUM

metals. This factor is rather constant and may easily be taken as

$$C = 2.6/7.7 = 0.338.$$

In case the structural part be subject to either pure tension or compression, it is obvious that the product of the two factors, namely K times C, would represent the necessary weight to be employed for an aluminum or steel rod or bar respectively in order that in either case the same factor of safety for a steady load may be obtained. I have made special mention of a steady load, because the factor of safety would be an altogether different one in the case of a rapidly fluctuating or reversing load, as in such a case fatigue would have to be considered and aluminum is considerably inferior to steel as far as fatigue is concerned. The product $K \times C$ is a direct function of K only and it is an easy form to represent graphically. For instance, if we plot different values of K as abscissas and as ordinates we plot the product $K \times C$, as in Fig. 1, we can determine at a glance from the ordinates the weight of an aluminum part corresponding to an equally strong ferrous metal part.

In case of bending, we have a slightly different problem, as we then have to take into consideration the sectional modulus. We may agree on a section of let us say a width equal to three-eighths of its height and inasmuch as the sectional modulus is determined by the width and the square of the height divided by 6, we have in case of ferrous metals

$$3/8\, h^3 \div 6 \text{ or } 3\, h^3 \div 48$$

Denoting with h_a the corresponding dimension for an aluminum section, it is obvious that the section should be K times as strong as the ferrous metal section and consequently have the following relation:

$$h_a^3 \div 48\, K = h^3 \div 48$$

From this it follows that

$$h_a = h \sqrt[3]{K}$$

Inasmuch as the weight is proportional to the area of the section, we would have a relation between the weight of a ferrous metal lever and that of an aluminum lever,

$$(3\, h_a^2/8) \div (3\, h^2/8) = h_a^2/h^2$$

Substituting for h_a, we obtain

$$(h^2 \sqrt[3]{K^2}) \div h^2 = \sqrt[3]{K^2}$$

If we multiply this weight ratio by our previously obtained constant, $C = 0.338$, we have a direct relation between the weight of an aluminum lever and that of a ferrous metal lever, both being designed to give the same factor of safety.

In cases where the deflection is of the greatest importance we must bear in mind that the moment of inertia is the determining factor, and this is determined by the fourth power of the sectional dimensions. For instance, the moment of inertia of a section similar to that previously considered for bending would be expressed by

$$3/8\, h^4 \div 12 = 3\, h^4 \div 96$$

Inasmuch as the modulus of elasticity of steel is approximately three times as large as that for aluminum, it is obvious that the aluminum section should be such that the moment of inertia is three times as large as that pertaining to the steel section. This insures equal rigidity and may be mathematically expressed by

$$(3\, h^4 \div 96) \times 3 = 3\, h_a^4 \div 96$$

From this it follows that

$$h_a = h \sqrt[4]{3} = 1.3161\, h$$

For a comparison for weights, we have to consider again the areas and similarly as before we have

$$3/8\, h_a^2 \div 3/8\, h^2$$

After substituting for h_a, we obtain

$$[3/8 \times (1.3161)^2 \times h^2] \div 3/8\, h^2 = 1.732$$

In other words, 73 per cent more area is required for aluminum than for steel in order that both sections may be of equal rigidity.

If we now multiply this constant factor by our factor C, we obtain

$$1.732 \times 0.338 = 0.585$$

Or in a case where deflection is to be held to a minimum, an aluminum part of only 58½ per cent the weight of a steel part can be substituted with equal satisfaction.

In conclusion, I would say that with steels we have reached some sort of an obstacle between what can be had out of the steel in the laboratory and what the factory can handle successfully. We can heat-treat alloy-steels easily to give a yield-point of over 200,000 lb. per sq. in. However, it would be utterly impossible with our existing cutting-tools to handle a steel thus treated successfully in the factory. It is, therefore, necessary to machine steel parts while yet annealed and heat-treat them after machining. This, as we well know, involves scaling and distortion and requires grinding after heat-treating. The only alternative is to sacrifice the best that can be had from steel and be satisfied with the heat-treatment giving a yield-point of only half of what the steel is perhaps capable of, and steel so heat-treated can be handled successfully in the factory. No such limitation is encountered in the use of aluminum. In fact, we are far from getting aluminum hard enough. It is necessary to look forward to a new development of cutting tools to give us greater speeds so as to utilize thoroughly this outstanding property of aluminum that we know is easy cutting.

MR. POMEROY:—Mr. Burkhardt's contribution is an important supplement to my paper. I may say that in general the substitution of aluminum for steel is most easily achieved when the steel part is bounded by the atmosphere. In the case of a crankshaft, for instance, although it might be possible to make this in aluminum and save weight in itself, the necessary increase in the diameter to obtain strength and stiffness and the further increase in the weight of bearings, due to the increased size, would practically balance the initial weight-saving on the crankshaft itself. The case of a connecting-rod is, however, very different and there are usually no pronounced limitations in the space available for the increased section required. The case is similar with an automobile frame. The car to which I have referred has a cast aluminum frame that has stood up perfectly under the most arduous conditions of road use. Its weight is about 60 per cent of that of a corresponding steel frame. In this particular instance the strength is conferred by the dimensions, while the material is of relatively low tensile-strength.

E. O. SPILLMAN:—We have been experimenting recently with a piston with slots, the piston having the ordinary clearances. Some of the test pistons developed piston slap. I have not taken them down to find out what the trouble is, but I think these pistons have collapsed on the off-pressure side. Should we increase the weight of this piston or increase the Brinell hardness? Does Mr. Pomeroy use aluminum shims on the big end?

MR. POMEROY:—If the piston has a slap as you describe, I think that it has collapsed. If this is the case, more metal is needed. We certainly do not recommend shims in the large end of connecting-rods.

MR. SHERBONDY:—Mr. Pomeroy compared the piston and connecting-rod weights in the Essex engine with his

own on a basis of cubic-inch capacity. I believe that these should be based on the horsepower output at any given speed. What does Mr. Pomeroy consider a fair stress for connecting-rods? And what does he consider a safe deflection for them?

MR. POMEROY:—I agree with Mr. Sherbondy that the basis for comparison of the weights of connecting-rods in various engines should be the horsepower developed at any given speed, since this is in terms of cylinder capacity if the brake mean effective pressure is the same in the two engines. In the case in question, the brake mean effective pressure of the Essex engine is about 10 per cent higher than that of my own engine and this correction though small should be allowed for.

The safe stress for an aluminum connecting-rod is rather difficult to state as the loading of a connecting-rod at high speeds is very complex. Using more or less accepted methods of calculation, I try to keep the combined stress in the shank of the rod down to about 5000 or 6000 lb. per sq. in. at 3200 r.p.m. This can usually be done if the section of the steel rod is increased by 20 per cent. Each case, however, demands individual consideration. In many cases the steel rods in use are stiffer than they need be from forging considerations. In other words, most forged connecting-rods would be considerably improved if the shank section were reduced by machining.

A MEMBER:—What does Mr. Pomeroy think of the possibility of using metallic magnesium for the same purpose as aluminum?

MR. POMEROY:—The use of magnesium is now being developed for a considerable number of automotive parts. Its application to connecting-rods is, however, a matter upon which nothing can be said at the moment.

A. J. FITZGIBBONS:—Has a successful universal-joint been made of aluminum?

MR. POMEROY:—In the case of a universal-joint the difficulty which arises is that of fixing the aluminum forging to the shafts themselves. There is no real reason why this cannot be done but so far the circumstances have not arisen to cause this to be done.

MR. BURKHARDT:—How about the ring type of universal-joint?

MR. POMEROY:—I do not see why aluminum could not be used for that.

MR. SHERBONDY:—Another point is the question of expansion, where the connecting-rods and the diameters of the pistons are small. Here we have to deal with 3 or 4-in. diameters and run at from 0 to 160 deg. fahr. temperature, so that the change in size becomes a very serious factor. In some cases it may cause failure. In fitting pistons as tightly as Mr. Pomeroy recommends, the only way to fit them is to heat them before putting them into the cylinders.

MR. POMEROY:—The expansion of aluminum is twice that of steel. For a 2-in. diameter shaft, a 100-deg. temperature-difference between the steel and the aluminum would mean a difference in the diameter of 0.001 in. and it is difficult for me to believe that this would make any great difference.

OIL CONSUMPTION

(*Concluded from p.* 494)

although I still argue it is impractical to put anything in a piston-ring that is likely to lose its efficiency. If you make, as Mr. Lítle says, a more or less feathered edge, which you could do by putting a groove in there, it is probable that it will retain its sharp edge if you make that angle acute enough. But, judging from the condition of the rings as I have seen them, it is possible that the wear would gradually reduce the efficiency of that edge to a point where it would not exercise the control that it did when it was first installed.

Regarding carbon deposit, it is a peculiar thing that in some territory I have been visiting recently, despite the fact that they pump a large quantity of oil and use much oil, I did not find excessive carbon-deposit. With so much oil on it does the piston not become hot enough to form carbon? Or, is the effect due to some fuel-condition that happens to exist in that particular territory? I think the latter is the case, because in Detroit, with the same amount of oil, the carbon deposit has been excessive.

I was asked if compression is any better with multiple-piece rings than with plain rings. That is so largely a matter of the circumferential ring-fit and the trueness of the bore, that I think I cannot say authoritatively that there is any benefit to be obtained with the multiple ring at this time. I do believe, however, that a multiple-piece ring that expands vertically and fills the groove up and down is likely to retain compression after long use better than the plain ring.

WAGES AND PRODUCTION

MONEY, the medium of exchange, is a necessity to modern civilization, but, unfortunately, its use sometimes obscures or distorts industrial facts. Producers, especially wage earners, are apt to think their comforts would be doubled if their pay were doubled. To analyze this, let us suppose that at a given time the pay of all persons engaged in any gainful occupation were doubled, while production remains the same. Is it not clear that the cost of everything would be doubled, and that each one, with his double pay, would be able to buy only as much as he did before? On the other hand, let us suppose that the pay remains the same to each, and that at a given time by improved machinery or otherwise, the productive force of each worker is doubled. Is it not plain that the cost of everything would be reduced one-half, and that each one, on the same pay, would be able to buy twice as much as before?

The only practical way to double the reward to workers is to double their products. Larger production per man, through machinery and improved methods accounts for the fact that workers are to-day able to enjoy comforts that 50 years ago would have been impossible. If money were eliminated, many of the popular delusions would not exist. All would understand that if every worker turned out twice as many products as formerly, deposited them in a public receptacle, and then each carried away what he desired, in proportion to what he had deposited, each would carry away twice as much, and thus have twice as much to enjoy.—George H. Hull.

Selection of Machine-Tools

By A. J. Baker[1]

Detroit Production Meeting Paper

THE problem of determining when to make a change of equipment by substituting new machine-tools for old, or special machines for standard, is carefully investigated. The fact that most manufacturers already have a surplus of machine-tools on hand on account of the demand for excessive production caused by the war makes the problem one not of providing for increased production but of decreasing its cost. The advantages and disadvantages of both special and standard machine-tools are weighed and the conclusion is reached that, although the ability of a special machine to produce pieces in fewer seconds is usually greeted with enthusiasm, other considerations such as the possible changes of the design of the pieces to be made, the inability to secure repair parts quickly, the dearth of skilled labor and the waste caused by employing inefficient help may make the change inadvisable. A method of analysis is given, by which an executive can determine how many cars of a particular model must be produced before a change of equipment can be justified.

I PROPOSE to lay down some general principles by which equipment can be scrutinized and the desirability of installing it determined. The title of this paper indicates machine-tools only, and since the application of these principles will be found to be greater with machine-tools than with any other type of equipment, we may let the title stand. I shall make a difference, however, because an executive, when equipping a plant, must select some items of equipment, not necessarily because he can effect a saving by them, but because he cannot produce a commercial success without them.

It is just as important for an automobile to have a body as to have a differential gear, but since the differential gear can be produced in a variety of ways and the sheet metal of the body in practically only one, the question of proper selection becomes much more important on the smaller and less expensive equipment required for the differential than for the heavy and expensive presses required for the body. Generally speaking, these principles apply to the selection of such machinery as lathes and vertical drilling, grinding, broaching, shaping, gear-cutting and milling machines, standard lines of wood-working machinery, hammers and the smaller sheet-metal presses. And in outlining those machines we must consider also those that were specially developed. Although they are described under other and special trade names, yet in view of the work produced these machines still come under the same general classification that is applied to the simpler standard machines.

A primary consideration that an executive must give to any purchase, be it design, material or equipment, must of course be its suitability for the purpose intended; another is the availability of a source of supply. Touching for a moment on this second point, we may look into the source of supply of the machine-tool industry during the last 10 years.

One extremely favorable aspect of the matter is that there is no apparent tendency of the machine-tool industry to become monopolistic in character. It is true that an association exists and it is also generally true that such associations ultimately must be paid for by the consumer. Many examples of this sort no doubt present themselves to you. However, since the manufacture of machine-tools apparently has always attracted a number of new devotees each year and since the various establishments range in size from those employing 50 men to those employing from 3000 to 4000, we can feel reasonably well assured of a diversity of interest and of sufficient competition to make it appear unlikely that any association can dictate to us as to the equipment we shall buy or the prices we must pay. In addition to this, the very remarkable growth of the machine-tool industry must not be forgotten. This Country is, without doubt, a greater producer of small and medium-size machine-tools than is any other. It does not stand proportionately so high in production of the heavier types of machinery, since much of this kind of equipment is produced in quantities so small that it does not lend itself to American methods of production and calls rather for the individual skill that is found more highly developed in the principal European countries. Nevertheless, as a whole, we have at hand all that is best in design and in workmanship of that class of machinery that is particularly applicable to the automobile trades, and which may be covered by lathes up to 36 in., planing machines up to 56 in., radial drilling machines up to 5 ft., milling machines up to No. 4 and gear-cutting equipment up to 48 in.

Besides we have an unquestioned superiority in the matter of those special highly productive machines that are developments of the standard equipment mentioned above and owe their inception so largely to the mass production of the sewing-machine, typewriter and automobile industries.

The Machine-Tool Industry

Diverting for the moment to the development of the machine-tool industry, prior to the war the number of men employed in the United States in the construction of machine-tools was approximately 33,000 and the output was valued at approximately $45,000,000 per year. At the peak of production during the war over 80,000 men were employed and the output was estimated as somewhere between $400,000,000 and $500,000,000 per year. These valuations, of course, do not express accurately the number of machines produced because the cost was increased very materially during the war. But, making due allowance for the non-employment prior to the war, the overtime work during the war, and the 100-per cent addition to the price of the machinery, it is reasonable to estimate that our machine-tool productivity of to-day, if stressed to its maximum, would be at least two and one-half times that of 1913; and it is further to be noted that the larger part of this increase is in the field of the small and medium-size machine-tools that I have already specified. Of course, a certain amount of increase and of development of production would have come in any case, through the normal processes of time and evolution. But no one I think will argue that the demand has as yet caught up with the unusual jump in machine-tool productivity that the war caused, nor will anyone be disposed to doubt that the vast majority of our factories

[1] Production department, Willys-Overland Co., Toledo.

during that period so added to their equipment that their normal demands, with a requisite allowance for the increase in equipment needed to meet their increasing trade, have for some time past been discounted. The great majority of the larger automobile factories possess surplus equipment, the full utilization of which is not likely to occur for some time to come. Some of this equipment has been so strained and injured that it must be replaced within a much shorter period than would be the case had it been operated under peace conditions. But, even allowing for this, I think you all will find that the factories you represent possess far more equipment of the standard types than can be utilized, particularly if the peak points in the production of automobiles could be ironed out. Consequently, the machine-tool builder, who looks toward a full utilization of his plant, will use all his engineering ability to develop some new machine, the output of which shall be so great that it will relegate to the discard all the machines previously produced by him, even though they may have been so well constructed and so well used that their productive life is still a matter of several years. He will do this on the theory, of the accuracy of which his sales department will endeavor to convince you, that you cannot afford to be without the newer machine because of the marked increase in production of the newer tool. If we could buy machines solely on the increase in production, the road would be easy, but this we should not do.

In the great majority of cases, assuming that a condition of a surplus of equipment does prevail, then the measuring stick by which we shall consider these offers is not increased production but decreased cost; and the two do not always go hand-in-hand. I am not dealing with a condition in which increased production is the essential thing from the viewpoint of the factory, because I do not believe that to be the case in most factories. My whole argument is built upon a belief that most of us have carried over from the war more machine-tools than we would by this time have acquired in normal times and under normal conditions, and that our problem is to determine whether we can afford to keep these machines or can dispense with them. Of course, if we are faced with an addition to our equipment that will permit us to produce more cars per day, our problem is greatly simplified since we would have only to select the machines that show the highest productive ability and apply to them the same general rules that will be laid down for the other case.

I think the foregoing should convince us that we have an ample source of supply; that it cannot become monopolistic; that the increased facilities at the disposal of machine-tool builders and their desire to utilize those facilities will lead them to the development of newer and better machines; and that, if we can exercise some influence, these machines may in the truest sense of the word be economical from the standpoint of the user. So much then for the market and the source of supply.

Cost of Labor Per Car

The third principle to be considered is the importance of a reduction in the cost of labor per car; you will please note that I do not say reduction in the price of labor. Our industry is so unfortunate as to be one in which the cost of labor is by no means equal to the cost of material. This fact makes it difficult to iron out our production schedules so that the same number of cars shall pass through our factories day after day. The demand for cars is more or less seasonal; that demand, reflected back to the factories, gives us our dull and prosperous periods, which we can not guard against by building up a stock of cars during the dull period, because of the tremendous inventory that we would accumulate by so doing.

Consequently, our industry offers its employes a relatively intermittent employment. To keep approximately the same number of employes throughout the year is given only to a very few of the larger shops and to a greater proportion of the smaller shops. Therefore, at certain periods, the employment department is called on to supply machine operators at a time when all other automobile manufacturers are clamoring for them. The result is that skilled operators cannot be secured and we must entrust our work to help of no skill or training in the manipulation of the machine. The automobile industry has never tackled in a large way the problem of instructing help, so that an adequate supply shall always be available. It has taken its skilled help from the other machine-tool-using industries, usually paying higher wages than most other industries could afford, and has never erected the machinery to replace the natural decrease in the available number of skilled men, or reciprocated by turning over to other industries trained men to take the places of those that have been taken.

As to the wisdom of this course there can be no question, but we are facing a condition, and those of us who select the machinery must bear in mind the type of help that may operate it. Machines that call for adjusting by hand during their operation, for accurate reading of dials or indicators, for careful setting up of the work in the machine, for a complex cycle of operations involving a developed mentality, all are to be decried, for not only do such machines limit the number of operators available, but under the stress of production the amount of scrap that the machines will produce is always entirely out of proportion to that produced by simpler equipment.

The Special Machine

A natural development of the above line of thought leads us to the special machine. By this I do not mean the single-purpose machine or, better still, the single-piece machine. There is a marked difference here that must not be lost sight of; and our failure as an industry to keep this difference clearly before us has led to the adoption and use of some machines that cannot be regarded as wholly satisfactory from an economic standpoint. In an enthusiastic endeavor to reduce time and to simplify operations, a number of machines have been developed that are useful for one piece only. They act as a deterrent from change in design and, generally speaking, are open to these objections.

(1) Their original cost must be great because the engineering and designing must be absorbed by the few machines that can be made on those models

(2) There is always considerable delay in producing them, so that the loss on account of the continued use of the older machine until the single-piece machine has been developed and tested out goes far toward overcoming the difference of the cost of labor between the single-piece machine and one of more general application that could be purchased as standard

(3) Since most machine-tools have been through a long process of development, it is certain that most special machines must pass through a long experimental period before they can reach the ideal set up by their designers, this adds further to the delay in obtaining full production

(4) The risk of break-down is much greater

(5) The delay in securing parts for replacement will be greater since all such parts are likely to be special
(6) The retention of an additional machine as assurance against break-down will often run the investment into large figures
(7) The difficulty of instantly replacing an operator
(8) The likelihood that special tools and fixtures must be designed and maintained
(9) The tendency of designers to incorporate elaborate tooling set-ups into such machines cannot be overlooked

All these are points of general application which are apt to be overlooked in the enthusiasm with which one views the statement that such a machine will turn out a given piece in so many seconds less than will a machine of a standard type. Often after a single-piece machine has been installed and satisfactorily operated, after its peculiarities of operation and tools have been fully understood and an organization has been trained that is able to maintain it in a state of efficiency, there is still the ever-present danger that a change of design may render the machine of no value whatever. There are to-day in the second-hand salesrooms so many of these machines that are without adjustments and are made so that they can produce only one piece that we need not go farther to see that we should step with caution.

Such machines have no value when divorced from the original purpose for which they were designed. A standard machine-tool, on the contrary, has a fixed market-value that depends upon its age and condition; and this value, carried on the books, can always be regarded as an asset. A special machine is apt to be carried on the books and to be depreciated by a nominal sum each year until a time comes when it is desired to turn the machine into dollars. A marked reduction in the inventory value must then be made through the inexorable law of supply and demand. A standard machine, on the other hand, can be transferred from one department to another and from one piece to another; its operators form a class and may be advertised for and hired under a classification, after the rates have been determined according to the location; the setting-up of the machine becomes a standard operation; the design, purchase and maintenance of the tools are all matters of routine. In the event of a break-down, though only one machine may be in use, it is possible to secure repair parts almost immediately from the builder and with a reasonable guarantee of interchangeability.

Between the single-piece machine and the standard machine-tool is the safe position. Some machine-tool builders already have recognized, and there is no doubt that others will recognize, the special needs of the automobile business. They have produced machine-tools in which the feeds and speeds cannot be changed at the will of the operator but can be changed at the will of the executive by the transposition of gears. These machines permit adjustments but only by the set-up man. They are constructed liberally along the lines of spindles, slides, gearing, pulleys and the like and preferably are over-designed for the power that they will consume. They are lubricated fully and automatically and do not require the use of the oil-can. In the hands of the operator they are only single-piece machines and as such may be designed with a reserve of power and a rigidity much in excess of the more universal type of machine because their application is not so constrained, and they can be regarded as a perpetual asset even though the model, or the detail of a model, were discarded and another took its place.

The same general line of reasoning will apply to tools and fixtures. Immense sums of money are spent in providing new tools when models are changed or improved. These sums may be and frequently are calculated, and the money is set aside to meet the expenditure. The maintenance and upkeep of the tools depend largely on their standardization, which is more difficult if single-piece machines are used, since the designer is apt to build his tools, as well as his machine, to suit the piece. If we deplore the reduction in the number of skilled machine operators, how much more should we deplore, and at the same time censure ourselves for, the reduction in the number of skilled tool and die makers.

It is true that an attempt has been made, and in some shops is well under way, to split up the tool-making and the die-making departments into various groups. But this, of course, is not applicable to the smaller shops, and at its best can only reduce the requirement and not abolish it. The tool designer is another of our operating units that each year is becoming more rare. I do not mean that we cannot get enough applications from tool designers, but I do say that a much lower percentage of capable men is to be found. The vision and the administrative capacity may be there, but the instruction or apprenticeship course that develops a high-grade machinist, a tool and die maker or a tool designer is very sadly lacking. Many of the fixtures that we apply to-day either to standard or to special machines bear evidence of having been made by a novice. There is a glorification of the complicated. The injunction to make two ears of corn grow where one grew before evidently has been taken literally.

If any of you have analyzed the tools and fixtures in your own shops and have compared them with simpler fixtures, not from the point of view of theory or design, but from that of practical application and of how much a part produced will cost, you will be ready to agree with me on this point. I have in mind a particular example in our factory, a certain brake connection in which a slot has to be milled to remove a binding strip that holds the two halves of a piece together during the casting process. The removing of this binding strip calls for no particular accuracy, requires no power and would be regarded as a simple operation to be accomplished on a hand milling machine with a very simple fixture; the total cost of the complete equipment would not exceed $500. Such an equipment could produce approximately 700 pieces per day. With an unskilled operator, a cheap tool equipment, no floor space and practically no tool-designing or tool-maintenance charges, two of these equipments would have taken care of all the requirements of our plant for a long time. Nevertheless, the actual equipment installed consisted of a very large rotary milling machine, upon the table of which was mounted a fixture that accommodated approximately 40 pieces, the fixture and the machine in combination costing about $6,700. One machine would, of course, take care of the requirements of the plant but, as an assurance against break-down, a duplicate equipment was ordered, so that the investment was about $13,400, or $12,400 in excess of the first mentioned equipment. Had the second machine not been ordered and a second fixture been deemed sufficient, there would still have been an outlay of about $9,000.

It would be easy to show that the big machine with one operator, on a basis of 600 cars per day, would produce a piece more cheaply than the two machines with two operators; but this is a condition that we, and I think most of you, do not experience. We may have a production of 600 cars per day for 1, 2, 3 or 4 months but we do not have it for 12 months. We could afford

to run those two small machines with two operators during our peak period, since the cheapest kind of help could be used on them, better than we could afford to spend the money that was spent for the expensive equipment. If we do the obvious thing, discard this casting and use in its place the stamping, we shall have on our hands two fixtures, one of which costs more than the full machine and fixture equipment that was considered in the first case. These fixtures have no resale value and reduce our inventory or assets by the amount of their original or depreciated value. Furthermore, such a machine, with its multiplicity of holding devices, will produce work that varies more than that which comes from the simpler machine. The floor inspector, passing from time to time, can take one of the pieces from the small machine and be sure that those that preceded it will have like accuracy. If a machine has a multiplicity of holders he cannot be so sure and the inspection charge will be increased. The scrap will be increased for the same reasons that make for a higher inspection charge. As the machine is run under the conditions of stressed production, you will find that some of the compartments are out of order and cannot be used, so the vaunted high production may be reduced, depending upon the number of compartments that are discarded. You may say that all this is bad management, that the compartment should not be permitted to get out of order, but we are talking as practical production men and we know that if a fixture at our peak period will produce three-quarters or seven-eighths of its true output, we are likely to continue in that state until a letting-up of the demand permits us to repair it.

I shall touch also upon the importance of avoiding break-downs that call for the services of skilled tool makers when such men are at a premium. If our equipment is of such a type that the average machinist can effect a satisfactory repair, we shall be that much ahead when the tight point comes and calls for immediate repair.

Skilled Workmen for Standard Machines

Another point that we must consider in the use of standard machines is the supply of skilled help that is yearly being turned out of the plants in which these machines are produced. Some of the machine-tool builders make a special point of training men, either in their own plants, or those of their customers, and of instructing them in the better handling of the machines and in the adjusting and setting-up, even to the point of effecting repairs. Such men are the nucleus around which a classification of labor is built; they call for no breaking-in and for that reason simplify the labor problem. The main reason why companies take this step is that most of the machines they produce were considered in the past to be somewhat more complicated than ordinary machines of that period and, to offset a high tool-repair or maintenance charge being made against the machines, which would of course react against their sale, they have seen fit to train satisfactory operators; of such operators we should avail ourselves thoroughly. These men should, wherever possible, be incorporated into a machine-repair gang, because it goes without saying that the more complicated the machine, the more skill and special training required to dismantle and repair it. Much harm may be done by unskillful attempts to repair a machine.

Basis of Purchase

Now, having in mind these general considerations, we come to the reasons for purchasing new equipment or new machines. The one most frequently encountered is that the new machine will save money. It is not always expressed that way; it is sometimes put that the new machine will reduce the labor cost or will turn out a piece more quickly than under the old method; but these are not the real things to be considered. The only satisfactory reason is to reduce the cost and not to reduce the labor charge or increase the production per man; and in this cost reduction appears the consideration of the items that I have already touched on. The second reason is to increase production; in other words, to turn out more parts per year or per season. In this case the consideration will be whether to put in more machines of the type already in use or to purchase some machine that was an improvement but of the same general type, or to get an entirely new kind of machine.

There is much to be said for maintenance standards. If the records show that the tool you have been using is up to the average in productivity, it would be foolish to change to another make, even if a somewhat greater output could be shown. Unfortunately many machine-tools of the same general classification differ so much in detail that the equipment of one cannot be transferred to another; the T-slots in the tables, the taper hole in the spindles, the thread on the spindles, the form of the tool-holder, the method of clamping the tools, the arrangement of the control levers all these differ very widely. You are therefore forced to make up special fixtures differing in some details from those that you have been using on other machines. This means that if a break-down occurs, and you have planned for it and have the extra tools available, you will have had to carry just twice as many fixtures in excess of actual requirements. If you have more than one make of machine you will not have the facility of immediate interchangeability; you will not be able to transfer the operators with any degree of certainty; the foremen will spend much more time in the instruction of the men; the time-study department will have to make changes in the times, because the speeds and feeds may differ somewhat; and it may mean even an adjusting of rates. Further, you will have to keep in stock certain replacement parts for these machines; that, of course, will be doubled in number if you have in use more than one type of machine.

Now, if we decide to put in an entirely new type of machine, we should give the matter a very careful analysis. The blanks that we are using at the Willys-Overland plant are shown. They can be used with additional machines, as the need of such machines appears in our schedule of production and also with new machines that are brought to our attention through the production of our competitors' shops, the trade journals or the visits of representatives of the builders or vendors of the machines. On the first blank reproduced you will notice the usual information as to the name of the part and the company by which the proposal is submitted and the basis on which the figuring is done so far as the number of cars per day is concerned. From there on a detailed comparison is made that gives the current operation as against the operation suggested, the name and number of machines required, the time study, the time per piece, the production per machine per 8 hr. and the cost per hundred.

I fear, generally speaking, that is all the information that is considered in the purchase of new equipment; we do not figure on the cost per piece or per hundred expressed in wages paid out on the job. You will note, however, that we go a little farther; we have specified the present resale value of the machinery now installed. This is to be used in replacement and

Oct. 24, 1922.

PROPOSED METHOD OF MACHINING PART No. **300,239—CRANKSHAFT**
Submitted by: **JONES & LAMSON MACHINE CO.**
Compared with our present method, figured on a basis of **500** cars per 8 hr.

PRESENT METHOD

Model 4—1 Per Car

Operation	Name of Machine	Machines Required	Time Study	Production per Machine in 8 hr.	Cost per 100	Present Resale Value of Machinery
Face Sides and Turn Flange	**18-In. American Lathe**	5	14.0	112	$4.00	$535.00
Face Inside of Flange	**18-In. American Lathe**	2	42.5	340	1.30	$535.00
Space and Rough Turn Rear Bearing	**18-In. American Lathe**	3	27.5	200	2.00	$535.00
Finish Turn Flange	**18-In. American Lathe**	2	39.0	312	1.40	$535.00
Under Cut Flange	**18-In. American Lathe**	2	55.0	440	1.00	$535.00
				TOTAL...	$9.70	$7,490.00

PROPOSED METHOD

Operation	Name of Machine	Machines Required	Time Study	Production per Machine in 8 hr.	Cost per 100	Cost of New Machinery
Turn Flange End for Grinding	**Double Carriage Fay Automatic Lathe (Flanders Type)**	6	10.8	92.8	$5.20	$3,143.50
				TOTAL...	$5.20	$18,861.00

REMARKS

Total resale value of machines for present method	$7,490.00	Present labor cost per hundred	$9.70
Total cost of machines for proposed method	$18,861.00	Labor cost by proposed method	$5.20
Total_________on machines for_________method	$11,371.00	Saving of labor per hundred	$4.50
Total cost of new tools for proposed method		Operators eliminated by proposed method	
Total increase of expenditure (including machines, tools and floor space)		Machines figured for factor of safety	
		Cost of taking down and installing new equipment	
Tools retired are good for production of______cars per day		Cars required to pay for new equipment	252,700
Value of tools retired (original cost of tools less 50% per annum)		(including machinery, tools and installation)	

Oct. 24, 1922.

PROPOSED METHOD OF MACHINING PART No. **300,239—CRANKSHAFT**
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PRESENT METHOD

Model 4—1 Per Car

Operation	Name of Machine	Machines Required	Time Study	Production per Machine in 8 hr.	Cost per 100	Present Resale Value of Machinery
Space Gear End Bearing	**18-In. American Lathe**	2	56.0	448	$0.99	$535.00
Rough Turn Gear End	**18-In. American Lathe**	2	42.5	340	1.30	$535.00
Finish Turn Gear End	**18-In. American Lathe**	2	55.0	280	1.58	$535.00
Neck and Chamfer Gear End	**18-In. American Lathe**	1	69.0	552	0.80	$535.00
Under Cut Gear End	**18-In. American Lathe**	1	162.0	1,296	0.39	$535.00
				TOTAL...	$5.06	$4,280.00

PROPOSED METHOD

Operation	Name of Machine	Machines Required	Time Study	Production per Machine in 8 hr.	Cost per 100	Cost of New Machinery
Turn Gear End for Grinding	**Double Carriage Fay Automatic Lathe (Flanders Type)**	3	23.6	202.9	$2.35	$2,883.50
				TOTAL...	$2.35	$8,650.50

REMARKS

Total resale value of machines for present method	$4,280.00	Present labor cost per hundred	$5.06
Total cost of machines for proposed method	$8,650.50	Labor cost by proposed method	$2.35
Total_________on machines for_________method	$4,370.00	Saving of labor per hundred	$2.71
Total cost of new tools for proposed method		Operators eliminated by proposed method	
Total increase of expenditure (including machines, tools and floor space)		Machines figured for factor of safety	
		Cost of taking down and installing new equipment	
Tools retired are good for production of______cars per day		Cars required to pay for new equipment	164,304
Value of tools retired (original cost of tools less 50% per annum)		(including machinery, tools and installation)	

Oct. 24 1922.

PROPOSED METHOD OF MACHINING PART No. **300,239—CRANKSHAFT**
Submitted by: **JONES & LAMSON MACHINE CO.**
Compared with our present method, figured on a basis of **300** cars per 8 hr.

PRESENT METHOD **Model 4—1 Per Car**

Operation	Name of Machine	Machines Required	Time Study	Production per Machine in 8 hr.	Cost per 100	Present Resale Value of Machinery
Face Sides of Flange and Turn	**18-In. American Lathe**	**3**	**14.0**	**112**	**$4.00**	**$535.00**
Face Inside of Flange	**18-In. American Lathe**	**1**	**42.5**	**340**	**1.30**	**$535.00**
Space and Rough Turn Rear Bearing	**18-In. American Lathe**	**2**	**27.5**	**200**	**2.00**	**$535.00**
Finish Turn Flange	**18-In. American Lathe**	**1**	**39.0**	**312**	**1.40**	**$535.00**
Finish Cut Flange	**18-In. American Lathe**	**1**	**55.0**	**440**	**1.00**	**$535.00**
				TOTAL...	**$9.70**	**$4,280.00**

PROPOSED METHOD

Operation	Name of Machine	Machines Required	Time Study	Production per Machine in 8 hr.	Cost per 100	Cost of New Machinery
Turn Flange End for Grinding	**Double Carriage Fay Automatic Lathe (Flanders Type)**	**4**	**10.8**	**92.8**	**$5.20**	**$3,143.50**
				TOTAL...	**$5.20**	**$12,574.00**

REMARKS

Total resale value of machines for present method	**$4,280.00**	Present labor cost per hundred	**$9.70**
Total cost of machines for proposed method	**$12,574.00**	Labor cost by proposed method	**$5.20**
Total________on machines for________method	**$8,294.00**	Saving of labor per hundred	**$4.50**
Total cost of new tools for proposed method		Operators eliminated by proposed method	
Total increase of expenditure (including machines, tools and floor space)		Machines figured for factor of safety	
		Cost of taking down and installing new equipment	
Tools retired are good for production of_____cars per day		Cars required to pay for new equipment (including machinery, tools and installation)	**160,530**
Value of tools retired (original cost of tools less 50% per annum)			

Oct. 24, 1922

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Compared with our present method, figured on a basis of **300** cars per 8 hr.

PRESENT METHOD **Model 4—1 Per Car**

Operation	Name of Machine	Machines Required	Time Study	Production per Machine in 8 hr.	Cost per 100	Present Resale Value of Machinery
Space Gear End Bearing	**18-In. American Lathe**	**1**	**56.0**	**448**	**$0.99**	**$535.00**
Rough Turn Gear End	**18-In. American Lathe**	**1**	**42.5**	**340**	**1.30**	**$535.00**
Finish Turn Gear End	**18-In. American Lathe**	**1**	**35.0**	**280**	**1.50**	**$535.00**
Neck and Chamfer Gear End	**18-In. American Lathe**	**1**	**69.0**	**552**	**0.80**	**$535.00**
Under Cut Gear End	**18-In. American Lathe**	**1**	**162.0**	**1,292**	**0.34**	**$535.00**
				TOTAL...	**$4.93**	**$2,675.00**

PROPOSED METHOD

Operation	Name of Machine	Machines Required	Time Study	Production per Machine in 8 hr.	Cost per 100	Cost of New Machinery
Turn Gear End for Grinding	**Double Carriage Fay Automatic Lathe (Flanders Type)**	**2**	**23.6**	**202.9**	**$2.35**	**$2,883.50**
				TOTAL...	**$2.35**	**$5,767.50**

REMARKS

Total resale value of machines for present method	**$2,675.00**	Present labor cost per hundred	**$4.93**
Total cost of machines for proposed method	**$5,767.00**	Labor cost by proposed method	**$2.35**
Total________on machines for________method	**$3,092.00**	Saving of labor per hundred	**$2.58**
Total cost of new tools for proposed method		Operators eliminated by proposed method	
Total increase of expenditure (including machines, tools and floor space)		Machines figured for factor of safety	
		Cost of taking down and installing new equipment	
Tools retired are good for production of_____cars per day		Cars required to pay for new equipment (including machinery, tools and installation)	**116,240**
Value of tools retired (original cost of tools less 50% per annum)			

wherever additional machines are installed; and against it we place the cost of the new machinery. In the tabulations at the bottom of the chart we show the total expenditure incurred, balancing the resale value of the machinery to be discarded against the expenditure required for the machinery to take its place. We add to this the cost of the new tools required for the proposed method and, if an increase in the floor space is required for the new tool, that also appears. Each foot of floor space carries a certain charge that varies with the building, and includes the items of power, light, heat, water, insurance and the like; in other words, a floor-space charge that is not an overhead charge. Below this is an item that may be considered only when we intend to change over to reduce costs, as it gives the production per day that the tools to be retired if the contemplated action is taken would be good for. This figure must be considered in connection with the actual labor cost of the parts, because an executive passing on this matter must know the contemplated production, as he would incline favorably toward the new equipment if he found that the old equipment were taxed nearly to its productive limit.

Below that appears the value of the tools retired, which is the original cost of the tools, less 50 per cent per year. In other words, if the special tools and fixtures had been used for a few months only, we should depreciate our inventory by the full value, or cost, of the equipment at a figure that would be carried on our books, and at the end of the year that equipment would be written off 50 per cent, the next year 50 per cent of the remainder, and so on.

A very material reduction thus takes place in the inventory value that avoids the piling-up of a so-called asset that really is no asset at all. Nevertheless, if no consideration is given to the inventory value of these tools, you might by carrying out the matter to a ridiculous extreme, wipe out in 1 day from the book value of the stock the whole item that is classified as small tools and fixtures and have nothing to show for it. Such action, of course, would involve you at once with the accounting department, and be very poor business. I do not wish to convey the impression that we actually write off our small tools, jigs and fixtures at the rate of 50 per cent per year, but for the purpose of figuring against contemplated installments, particularly if it is for the purpose of effecting reductions in cost and not of taking care of extensions in volume, this makes a rather satisfactory arrangement.

The next two items show the labor cost at present as against that of the proposed method, and the saving in money in labor charges. The next item, which is again an intangible one, shows the number of operators that would be eliminated by the proposed method. This is a matter in which the factory executive and the employment manager are vitally interested. Labor troubles and short labor markets will always be with us, and the larger and more unwieldy the business becomes in point of the number of employes, the more likely are we to have trouble in procuring and maintaining an adequate labor supply. The proportion of machines taken into account in determining a factor of safety and the cost of taking down and installing the new equipment are then listed, after which the gist of the whole matter is expressed in the final line "The number of cars required to pay for the new equipment." It is of no use to say that the equipment will pay for itself in 1 year or in 2 years, because time is an uncertain element. Few men are able to estimate exactly how much work will be produced by a factory in 1 or 2 years. They may give a general average, but a progressive company should climb steadily. It seems better, therefore, to say that to pay for this saving a certain number of cars will be required. This gives two avenues for criticism, (*a*) the approximate time the cars will take to absorb this expenditure can be determined at the date of consideration by our knowledge of the expected output; (*b*) the number of cars that we are likely to make before the part in question is changed and the equipment is thrown out of use. When we are considering the installation of equipment that is made necessary by an increased production, this last item is not very important, but when we are approached for the consideration of some new machinery to take the place of that for which we already have spent our money and which already has been installed, this item becomes of paramount importance.

It has been very interesting to make these comparisons between some of the oldest equipment now in use in the Willys-Overland plant and some of the latest and most uptodate equipment that is being offered. We find that, even when a great reduction in time per piece is guaranteed by the machine builders and a good resale price is allowed for the old equipment, the actual number of cars required to pay for the new equipment is such that a rather effective damper is put on many installations that otherwise look as if they should be approved and authorized at once. I think that is because we consider in the installation of machines not only the cost of labor but also the inventory value of the equipment already in use.

As a matter of fact, after a study of 15 pieces as manufactured on our small car, substituting for the present equipment the latest and best standard machine-tools as specially developed for the automobile industry, we find that an expenditure of $132,000 is required to effect a saving per car of approximately 42 cents. Against this we have an expected resale value of machinery now in use of not more than $25,000; and this I believe is taking an optimistic view as the book value of the machinery stands at a very much higher figure than that given. In addition, some $13,500 worth of special equipment, book value, would have to be discarded, so that we should have to produce about 179,000 cars of this model before we would be justified in throwing out what is universally regarded as old machinery to give place to what is regarded as the very latest product of the machine-tool builders' art. There are, of course, some items in which a saving can be made in from 40,000 to 50,000 cars; some of them, however, run up to nearly 500,000 cars, and I will say further that we have not included in our study some of the more elaborate equipments to amortize the expense of which would involve a production of nearly 1,000,000 cars. This is on a basis of labor-cost saving only and does not include burden saving which, though theoretically applicable, would nevertheless hardly be reflected in the cost for a very long time.

I am well aware that much exception can be taken to this line of reasoning. It does not make the easiest road for the machine-tool builder to follow, but I think the figures cannot be controverted.

SUMMARY

In summarizing, I want to make these points

(1) There is a surplus, both actual and potential, of machine-tool equipment of the standard types

(2) Machine-tool builders are devoting their thought to high-production single-purpose machines of standard types

(3) The craze for special machinery is passing

SAVINGS TO BE ACCOMPLISHED BY INSTALLATION OF NEW EQUIPMENT BASED ON THE PRODUCTION OF 500 MODEL 4'S PER DAY

Part No.	Name of Part	Name of Present Machinery	Name of New Machinery	Saving of Floor Space, Sq. Ft.	Increase of Floor Space, Sq. Ft.	Book Value Special Equipment To Be Discarded	Book Value of Present Machinery	Resale Value of Present Machinery	Cost of New Machinery and Tools	Required Expenditure	Saving per Car	Cars to Amortize at 500 per Day
300,562	Inner Brake-Band	2—Silver Drills	1—No. 2 Avey Drill	8	......	$564.00	$225.70	$159.00	$2,800.00	$2,641.00	$0.0060	221,700
303,584	Brake Locker Lever Bracket	4—No. 310 Baker Drills 4—25" Barnes Drills 1—8" Henry & Wright Drill	1—No 2 Avey Drill 1—No. 3 Avey Drill	97½	......	1,885.00	3,410.26	3,332.00	12,325.00	8,993.00	0.0470	191,240
300,387	Steering-Knuckle Arm	2—No. 310 Baker Drills 5—No. 4 Bardons & Oliver Lathes	2—Daniels Automatic Multiple-Spindle Chucker	113	......	2,475.00	7,808.35	5,981.00	18,868.00	12,887.00	0.0257	253,266
300,239	Crankshaft	6—16x32 Landis Grinders	6—Wickes Heavy-Duty Crankshaft Lathes	......	54	......	16,097.76	15,913.00	27,000.00	11,057.00	0.0773	146,357
300,180	Nut Welding ¼x28 Thread	1—Garvin Vertical Tapper	1—D12 Fox Multiple Drill and Tapper	......	......	35.00	411.57	364.00	3,233.00	2,869.00	0.0060	444,390
300,382	Front Axle	3—Espen Lucas Millers 2—25" Barnes Drills 3—No. 7 Becker Millers	1—Ingersoll Drum Type Axle Miller	243	......	3,393.00	9,860.46	10,344.00	14,386.00	4,042.00	0.0610	71,125
300,313	Piston Pin	4—10x28 Norton Grinders	2—Model B Sanford Centerless Grinders	70	......	......	9,692.84	5,826.00	5,000.00	......	0.0070	......
300,620	Brake Support Bracket	3—No. 1 Kempsmith Millers 1—No. 3 Kempsmith Miller	1—40" Ohio Rotary Tilting Miller	89	......	1,425.00	5,023.65	2,880.00	4,520.00	164.00	0.0170	120,897
305,166	Brake-Spring Bracket	2—No. 3 Kempsmith Millers 1—18" Cincinnati Miller 1—No. 7 Becker Miller	1—40" Ohio Rotary Tilting Miller	85	......	1,650.00	4,589.40	3,323.00	4,735.00	1,412.00	0.0120	134,437
300,385-6	Steering-Knuckle	4—25" Barnes Drills 1—No. 7 Becker Miller 1—No. 1 Tol. Hd. Miller	1—40" Ohio Rotary Tilting Miller	183	......	1,282.00	1,483.96	1,254.00	8,990.00	7,736.00	0.0400	202,549
300,385-6	Steering-Knuckle	2—16" American Lathes 3—3½x30 LoSwing Lathes	2—No. 9 LeBlond Multi Cut Lathes	42	......	337.50	4,679.24	3,454.00	4,564.00	1,110.00	0.0120	53,889
300,209	Camshaft	8—10x28 Norton Grinders	4—Melling Cam Turning Lathes	167	......	......	19,385.68	11 872.00	15,805.00	3,933.00	0.1020	42,761
300,675	Steering Arm	3—No. 4 Bardons & Oliver Lathes	Daniels Automatic Multiple-Spindle Chucking Machine	47½	......	318.75	4,683.00	2,511.00	10,050.00	7,539.00	0.0190	399,866
	TOTAL			1,144½	54	$13,365.25	$86,351.57	$67,243.00	$132,276.00	$65,859.00	$0.4220	156,064

(4) Special machinery will not always stand a financial comparison with standard machinery
(5) We are not, as an industry, facing our responsibilities in the matter of training operative help for tool and die work
(6) When considering new equipment we cannot disregard the inventory value of existing equipment and the loss that would be shown on our balance sheet if the existing equipment were converted from productive machinery into excess machinery that will have to be offered for sale
(7) The only good reason for installing new machinery, old machinery or any machinery, apart from those causes where a better qual:ty is demanded, is to reduce the total cost of production of the complete part

TRADE RELATIONS WITH SOUTH AMERICA

SINCE the war ended the European belligerents have sought to regain the markets in foreign countries that had been lost during the 4 years of conflict. In South America the United States had built up a vast foreign trade, supplying in large part the needs of the people there that had formerly been met by the United Kingdom, France, Germany, Italy and Belgium. The question was whether, on the renewal of competition from European countries, the United States would be able to hold the position it had won.

Up to the outbreak of the world-wide depression in 1920, the United States maintained its lead practically unimpaired, and in that year 42 per cent of South America's imports came from the United States, as against 15 per cent prior to the war and 46 per cent in 1917. The relative importance of the United States as a market for South American goods naturally declined in the face of Europe's extreme need of foodstuffs and raw materials. In 1920, 33 per cent of South American exports went to the United States, against 42 per cent in 1917 and 20 per cent, on the average, for the years before the war.

The United States is one of the greatest manufacturing countries in the world, but is unusual in that it produces most of its own foodsuffs and even a surplus for export. The only foodstuffs that this country needs to import in large quantities are the products of a tropical climate, such as coffee, cacao and sugar. A large proportion of the exports of Argentina and Uruguay is made up of wheat, flour and meat products, in which the United States is self-supporting. This situation tends to limit the possible volume of imports from Argentina and Uruguay, although there is an active demand in the United States for the industrial raw materials of these countries, such as flaxseed, wool and hides and skins.

In Brazil the important foodstuff exported is coffee, of which Brazil produces three-fourths of the world's supply. More than half the entire crop is sent to the United States. The other major food products, cacao and sugar, are imported into the United States in large quantities. Brazil's principal industrial raw material, rubber, goes almost entirely to the United States. The same is true of the nitrate and hides of Chile, the coffee and cacao of Ecuador, Colombia and Venezuela, and the copper, vanadium, rubber and cotton of Peru. The United States took 45 per cent of the total exports from these countries in 1919 and 47 per cent in 1920, as compared with 20 per cent from Argentina and Uruguay in 1919 and 19 per cent in 1920. In 1920 the United States took more than 85 per cent of the total exports from Colombia, most of which are products of a tropical climate.

These countries and the United States are best prepared to supply each other's requirements, and the commercial bonds between them should become more and more close. Normally, the United States imports more goods from the countries of South America than it sends to them. For the 5 years prior to the war the balance of trade in favor of South America averaged nearly $90,000,000 each year. The normal balance of trade in the future will probably be as large as or larger than that before the war, but the amount will be offset to a great extent by so-called "invisible" exports from the United States that have come into existence during the past few years.

Two items will serve as examples. In 1913, only 4 per cent of the shipping clearing from ports of the United States for South America with cargo was of American registry. In 1920, 52 per cent was of American registry. In the latter year the aggregate amount paid in freight rates to the shipowners of the United States by South American consumers of American goods was probably about $10,000,000. A second factor is the large increase in South American securities held in the United States. As is natural in a new territory in process of development, investments of foreign funds in South America are large. While the major part of this investment is still British and European, the volume of American investments has been substantially increased. On July 1, 1922, there were outstanding more than $400,000,000 of South American Government, State, municipal and corporate bonds that had been issued in this country, on which the annual interest charge is approximately $30,000,000. Of these securities the larger part has been negotiated during the last 3½ years, as is evidenced by the fact that on Jan. 1, 1919, there were only $60,000,000 outstanding. During the 18 months ended June 30, 1922, there were floated in the New York market some $334,000,000 of South American securities, as against $80,000,000 of such securities in London.

The United States is in a more favorable position to hold and build up a large trade with South America than before the war. Valuable relationships have been established, while the physical equipment for carrying on foreign trade, such as shipping facilities, has been increased and improved. It is not to be expected that the United States will regain the abnormal proportion of the South American trade that it held in 1917, but it is apparent that its share will be permanently larger than before the war.—*Commerce Monthly.*

Reports of Divisions to Standards Committee

THE following 16 Division reports of the automotive and parts and materials Divisions of the Standards Committee will be presented for approval at the Standards Committee Meeting on Tuesday, Jan. 9, at 10:30 a. m. in the south convention hall on the fifth floor of the Engineering Societies Building. The reports are printed in this issue of THE JOURNAL to allow sufficient time for the Society members and others to study the reports and prepare comments and suggestions for consideration at the Standards Committee Meeting.

Although only members of the Standards Committee may vote on the adoption of the reports at this meeting, discussion is invited from everyone, whether connected with the engineering, production or servicing branches of the industry, interested in the adoption in practice of the standards proposed.

It should be borne in mind that the recommendations of the various Divisions do not necessarily apply to present practice, although they are based to a large extent on it. They are intended to be followed by the various industries to which they are applicable when changes in design or production make it economically possible to do so. Therefore the general adoption in practice of a given recommendation may be a matter of months or years depending upon the conditions involved.

A general resume of the work of the Standards Committee during the current year is given on p. 555 of this issue. The detailed procedure followed by the Standards Committee and its Divisions is outlined on p. 556 of this issue.

AXLE AND WHEELS DIVISION REPORT

Division Personnel

G. W. Dunhan, *Chairman*	Savage Arms Corporation
C. C. Carlton, *Vice-Chairman*	Motor Wheel Corporation
R. S. Begg	Jordan Motor Car Co.
T. V. Buckwalter	Timken Roller Bearing Co.
A. C. Burch	Courier Motors Co.
R. J. Burrows	Clark Equipment Co.
L. W. Close	Bock Bearing Co.
J. Coapman	Russell Motor Axle Co.
C. S. Dahlquist	Eaton Axle Co.
F. S. Denneen	Grant Motor Car Co.
F. W. Gurney	Gurney Ball Bearing Co.
F. P. Hall, Jr.	Salisbury Axle Co.
G. W. Harper	Columbia Axle Co.
G. L. Lavery	West Steel Casting Co.
A. M. Laycock	Sheldon Axle & Spring Co.
H. V. Ludwick	Budd Wheel Corporation
C. T. Myers	Consulting Engineer
A. L. Putnam	Detroit Pressed Steel Co.
O. J. Rohde	Wire Wheel Corporation of America
H. Vanderbeek	Formerly with Timken-Detroit Axle Co.

PASSENGER-CAR FRONT-AXLE HUBS

(Proposed S.A.E. Recommended Practice)

The Axle and Wheels Division was appointed in 1921 as the successor to the Axle and Wheels Subdivision of the 1920 Truck Division, the Subdivision being given the status of a separate Division due to the importance of the subjects coming under this classification.

The principal work of the Subdivision since its organization has been the continuation of the front-axle hub standardization program instituted by the Subdivision in 1920. Following the adoption of the S.A.E. Recommended Practice on Motor-Truck Front-Axle Hubs, the Division continued its work looking toward formulating a standard for passenger-car front-axle hubs.

In order that the large amount of work involved in the formulation of such an important standard might not fall entirely on a few members of the Division, a Subdivision and, later, two Subcommittees were appointed to deal with different phases of the work. The personnel of the Subdivision and Subcommittees that formulated the present recommendation and are continuing the work as to other necessary features is as follows:

SUBDIVISION ON PASSENGER-CAR FRONT-AXLE HUBS

C. T. Myers, *Chairman*	Consulting engineer
T. V. Buckwalter	Timken Roller Bearing Co.
Claude Greenhoe	Hyatt Roller Bearing Co.
F. W. Gurney	Gurney Ball Bearing Co.
E. R. Jacobi	Hayes Wheel Co.
A. M. Laycock	Sheldon Axle & Spring Co.
G. L. Lavery	West Steel Castings Co.
A. L. Putnam	Detroit Pressed Steel Co.
O. J. Rohde	Wire Wheel Corporation of America
A. S. VanHalteren	Motor Wheel Corporation

ROLLER BEARING SUBCOMMITTEE

T. V. Buckwalter, *Chairman*	Timken Roller Bearing Co.
R. S. Begg	Jordan Motor Car Co.
L. W. Close	Bock Bearing Co.
C. S. Dahlquist	Eaton Axle Co.
A. M. Dean	Rubay Co.
G. W. Dunham	Savage Arms Corporation
Claude Greenhoe	Hyatt Roller Bearing Co.
C. T. Hagenlocher	Wright Roller Bearing Co.
A. M. Laycock	Sheldon Axle & Spring Co.
A. L. Putnam	Detroit Pressed Steel Co.
O. J. Rohde	Wire Wheel Corporation of America
R. G. Schaffner	Bower Roller Bearing Co.
L. M. Stellman	H. H. Franklin Mfg. Co.
H. Vanderbeek	Detroit, Mich.
A. S. VanHalteren	Motor Wheel Corporation

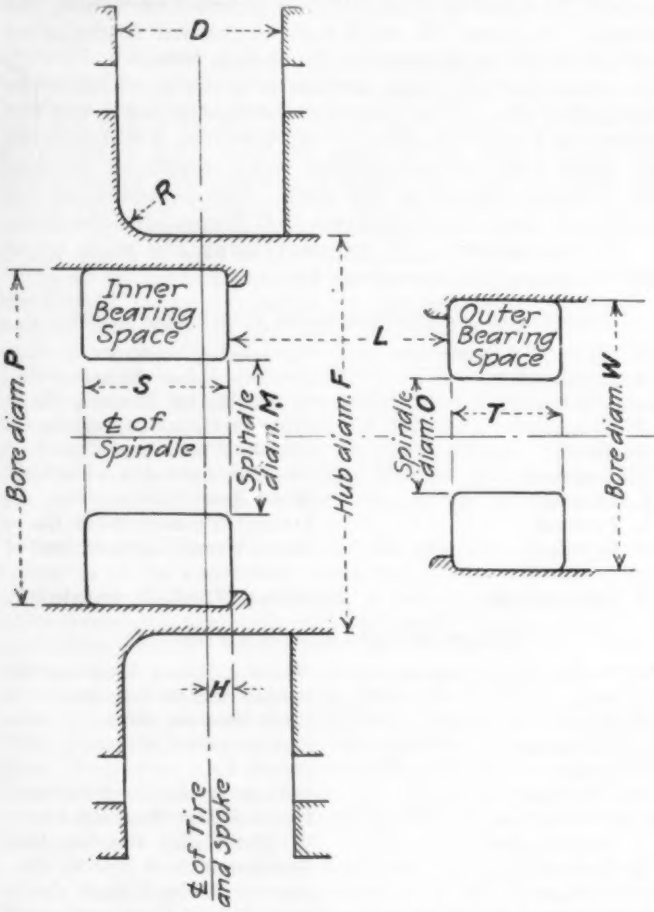
BALL BEARING SUBCOMMITTEE

F. W. Gurney, *Chairman*	Gurney Ball Bearing Co.
R. S. Begg	Jordan Motor Car Co.
H. E. Brunner	S. K. F. Industries, Inc.
E. R. Carter	Fafnir Bearing Co.
L. A. Cummings	Standard Steel & Bearings, Inc.
C. S. Dahlquist	Eaton Axle Co.
A. M. Dean	Rubay Co.
F. G. Hughes	S. K. F. Industries, Inc.
A. M. Laycock	Sheldon Axle & Spring Co.
A. L. Putnam	Detroit Pressed Steel Co.
O. J. Rohde	Wire Wheel Corporation of America
L. M. Stellman	H. H. Franklin Mfg. Co.
H. Vanderbeek	Detroit, Mich.
A. S. VanHalteren	Motor Wheel Corporation

The recommendation of the Subdivision was based largely on information obtained from passenger-car

manufacturers as to their current practice and from the files of the committee members. The Subdivision decided that five sizes of hub assembly, including the Ford type, would be sufficient to meet the requirements of the industry, the Ford type of spindle being included as it is suitable for light passenger-cars such as are being developed at the present time. The spindle diameters were selected from sizes most generally used and were classified according to tire sizes and approximate weights on the front axle as this method was considered the most logical.

As the actual practice followed for spacing the inner and outer bearings varied considerably, the method of spacing the bearings that was followed in formulating the present standard for Motor-Truck Front-Axle Hubs was used, this being to make the distance between the center-line of the bearings not less than 10 per cent of the tire outside diameter.



DIMENSIONS FOR INCH-SIZE TAPER-ROLLER BEARING HUBS

Hub and Spindle Number	Letter	RO	R1	R2	R3	R4
Inner edge of inner bearing to center-line of spoke	H[1]	−[illegible]	0	−3/32	−1/16	3/16
Inner bearing shoulder to outer bearing shoulder	L	3 [illegible]	2 3/32	2 [illegible]	2 [illegible]	1 [illegible]
Spindle diameter at inner bearing	M	1.1895 1.1890	1.3120 1.3115	1.3745 1.3740	1.4995 1.4990	1.6245 1.6240
Spindle diameter at outer bearing	O	¾"–16	0.9370 0.9365	0.9370 0.9365	0.9995 0.9990	1.1870 1.1865
Hub bore for inner bearing	P	2.7155 2.7140	2.6135 2.6120	2.9985 2.9970	3.1547 3.1532	3.2485 3.2470
Hub bore for outer bearing	W	1.9365 1.9350	2.1235 2.1220	2.1235 2.1220	2.4828 2.4813	2.8578 2.8563
Overall length of inner bearing	S	1.0425	[illegible]	[illegible]	1 [illegible]	1⅜
Overall length of outer bearing	T	[illegible]	[illegible]	[illegible]	[illegible]	1 [illegible]

[1] Minus dimensions indicate that the inner edge of the inner bearing is located to the right, or the side nearer the threaded spindle, of the center-line.

The inner edge of the bearing surface of the spindle shall be ¼ in. inside of the inner edge of the outer bearing.

Although it is the purpose of the Division to recommend hub dimensions for both taper-roller and ball bearings, it was decided at a joint meeting of the Axle and Wheels and the Ball and Roller Bearings Divisions on Oct. 4 that even though a considerable amount of work has been accomplished in establishing ball-bearing sizes for passenger-car front-axle hub applications, the work did not warrant submitting a recommendation at this time. As the work on roller-bearing applications had reached such a point that the boundary and spacing dimensions for the bearings and the corresponding spindle and hub dimensions could be recommended, such action was approved by the Divisions in joint session and subsequently by the Axle and Wheels Division. The recommendation completes a series of 10 applications of inch-size taper-roller bearings for front-axle spindles and hubs ranging from light passenger-cars to heavy motor-trucks, the sizes specified for the lighter type of motor trucks being the same for the heavier type of passenger cars. Therefore

> The Axle and Wheels Division recommends for adoption as S.A.E. Recommended Practice the accompanying series of inch-type taper-roller bearings for passenger-car front-axle spindles and hubs.

BALL AND ROLLER BEARINGS DIVISION REPORT

Division Personnel

F. W. Gurney, *Chairman*	Manly & Veal
C. M. Manly, *Vice-Chairman*	Railway Roller Bearing Co.
J. T. R. Bell	Norma Co. of America
G. R. Bott	S K F Industries, Inc.
H. E. Brunner	Timken Roller Bearing Co.
T. V. Buckwalter	Fafnir Bearing Co.
E. R. Carter, Jr.	Bearings Co. of America
D. F. Chambers	Bock Bearing Co.
L. W. Close	Standard Steel & Bearings, Inc.
L. A. Cummings	Savage Arms Corporation
G. W. Dunham	Long Mfg. Co.
R. G. Hendricks	New Departure Mfg. Co.
F. G. Hughes	Gilliam Mfg. Co.
G. L. Miller	White Motor Co.
A. J. Scaife	Bower Roller Bearing Co.
R. G. Schaffner	Cadillac Motor Car Co.
W. R. Strickland	Hyatt Roller Bearing Co.
R. E. Wells	Gurney Ball Bearing Co.

BALL AND ROLLER BEARINGS DIVISION REPORT

METRIC-TYPE THRUST BALL-BEARINGS

(Proposed S.A.E. Standard)

In 1918 the Ball and Roller Bearings Division recommended for adoption certain inch tolerances for metric-type thrust ball-bearings, favorable action being taken by the Society in August of that year. The recommendation specified only the tolerances for various ranges of the boundary dimensions because full information as to foreign practice was not obtainable owing to the war. Early in 1921 information was obtained as to European practice

D. F. Chambers, *Chairman*	Bearings Co. of America
Frank Beemer	Nice Ball Bearing Co.
H. E. Brunner	S. K. F. Industries, Inc.
E. R. Carter	Fafnir Bearing Co.
F. Alton Collins	Auburn Ball Bearing Co.
H. H. Edwards	Bantam Ball Bearing Co.
S. A. Strickland	Imperial Bearing Co.
H. Wickland	U. S. Ball Bearing Mfg. Co.

and a Subdivision appointed to extend the present S.A.E. Standard shown on pp. C39 to C42 inclusive of the S.A.E. HANDBOOK, the personnel of which is given on p. 530. The work advanced until it was possible for a progress report to be submitted at the June meeting of the Standards Committee this year. Since the June meeting it has been possible for the Subdivision to obtain agreement as to the double-direction flat-face and self-aligning types.

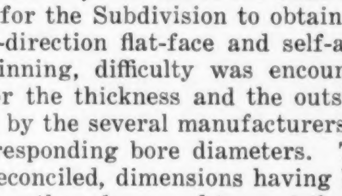
In the beginning, difficulty was encountered in that dimensions for the thickness and the outside diameters, as established by the several manufacturers, were not the same for corresponding bore diameters. These discrepancies were reconciled, dimensions having been generally increased rather than decreased to meet the existing individual standards, thus working toward the strengthening of thrust-washer sections and eliminating the weaker parts in the several series.

In the self-aligning series there was considerable variation in the thickness and the radii used in determining the curvative of the self-aligning seat. These differences have been eliminated and, in addition, dimensions giving the location of the radii have been specified. This is important, particularly to the users of self-aligning ball-bearings, as it is frequently desired to incorporate the self-aligning seat as an integral part of a mechanism.

In the proposed standards the present established dimensions of both foreign and American ball-bearing manufacturers were used as a basis for this work, but to obtain a consistent series of the double-direction type, it was found necessary to develop a new light series in both the plain and the self-aligning constructions. These correspond with the light series of the single-direction type. Therefore

> The Ball and Roller Bearings Division recommends that the accompanying series proposed by the Thrust Ball-Bearings Subdivision covering Light, Medium and Heavy Series for the Single-Direction Flat-Face Type, the Single-Direction Self-Aligning Type, the Double-Direction Flat-Face Type and the Double-Direction Self-Aligning Type of Thrust Ball-Bearings be adopted as an S.A.E. Standard.

The Subdivision report as received by the Division was accompanied by a minority report to the effect that the Subdivision report does not allow a sufficient amount of "land" in the retainer for good engineering practice. The Division recommended that the minority report be appended to the Division report in order that action would be taken at the Standards Committee meeting with a full knowledge of the questions involved. It was the consensus of opinion at the Division meeting that the dimensions finally chosen by the Subdivision allow for ample strength of separators or cages built in accordance with



SINGLE-DIRECTION, FLAT-FACE TYPE
LIGHT SERIES, METRIC SIZES

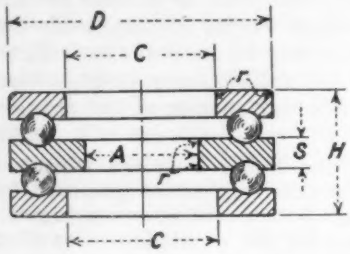
Bearing Number	Inside Diameter (B)		Diameter (C)		Outside Diameter (D)		Height (H)		Chamfer or Radius (r)	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TP-L-10	10	0.3937	11	0.4331	26	1.0236	12	0.4724	1	0.040
TP-L-12	12	0.4724	13	0.5118	28	1.1024	12	0.4724	1	0.040
TP-L-15	15	0.5906	16	0.6299	31	1.2205	12	0.4724	1	0.040
TP-L-17	17	0.6693	18	0.7087	35	1.3780	12	0.4724	1	0.040
TP-L-20	20	0.7874	21	0.8268	37	1.4567	12	0.4724	1	0.040
TP-L-25	25	0.9843	26	1.0236	45	1.7717	14	0.5512	1	0.040
TP-L-30	30	1.1811	31	1.2205	50	1.9685	14	0.5512	1	0.040
TP-L-35	35	1.3780	36	1.4173	55	2.1654	16	0.6299	1	0.040
TP-L-40	40	1.5748	41	1.6142	60	2.3622	16	0.6299	2	0.080
TP-L-45	45	1.7717	46	1.8110	68	2.6672	16	0.6299	2	0.080
TP-L-50	50	1.9685	51	2.0079	74	2.9134	18	0.7087	2	0.080
TP-L-55	55	2.1654	56	2.2047	78	3.0709	18	0.7087	2	0.080
TP-L-60	60	2.3622	61	2.4016	82	3.2284	18	0.7087	2	0.080
TP-L-65	65	2.5591	66	2.5984	90	3.5433	20	0.7874	2	0.080
TP-L-70	70	2.7559	71	2.7953	95	3.7402	20	0.7874	2	0.080
TP-L-75	75	2.9528	76	2.9921	100	3.9370	20	0.7874	2	0.080
TP-L-80	80	3.1496	81	3.1890	110	4.3307	22	0.8661	3	0.120
TP-L-85	85	3.3465	86	3.3858	115	4.5276	22	0.8661	3	0.120
TP-L-90	90	3.5433	91	3.5827	120	4.7244	22	0.8661	3	0.120
TP-L-95	95	3.7402	96	3.7795	130	5.1181	25	0.9843	3	0.120
TP-L-100	100	3.9370	101	3.9764	135	5.3150	25	0.9843	3	0.120
TP-L-105	105	4.1339	106	4.1732	140	5.5118	25	0.9843	3	0.120
TP-L-110	110	4.3307	111	4.3701	145	5.7087	25	0.9843	3	0.120

SINGLE-DIRECTION, FLAT-FACE TYPE
MEDIUM SERIES, METRIC SIZES

Bearing Number	Inside Diameter (B)		Diameter (C)		Outside Diameter (D)		Height (H)		Chamfer or Radius (r)	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TP-M-10	10	0.3937	11	0.4331	30	1.1811	12	0.4724	1	0.040
TP-M-12	12	0.4724	13	0.5118	32	1.2598	12	0.4724	1	0.040
TP-M-15	15	0.5906	16	0.6299	35	1.3780	14	0.5512	1	0.040
TP-M-17	17	0.6693	18	0.7087	38	1.4961	14	0.5512	1	0.040
TP-M-20	20	0.7874	21	0.8268	40	1.5748	14	0.5512	1	0.040
TP-M-25	25	0.9843	26	1.0236	48	1.8898	15	0.5906	1	0.040
TP-M-30	30	1.1811	31	1.2205	53	2.0866	15	0.5906	2	0.080
TP-M-35	35	1.3780	36	1.4173	62	2.4409	18	0.7087	2	0.080
TP-M-40	40	1.5748	41	1.6142	64	2.5197	18	0.7087	2	0.080
TP-M-45	45	1.7717	46	1.8110	73	2.8740	22	0.8661	2	0.080
TP-M-50	50	1.9685	51	2.0079	78	3.0709	22	0.8661	2	0.080
TP-M-55	55	2.1654	56	2.2047	88	3.4646	24	0.9449	2	0.080
TP-M-60	60	2.3622	61	2.4016	90	3.5433	24	0.9449	2	0.080
TP-M-65	65	2.5591	66	2.5984	100	3.9370	27	1.0630	3	0.120
TP-M-70	70	2.7559	71	2.7953	103	4.0551	27	1.0630	3	0.120
TP-M-75	75	2.9528	76	2.9921	110	4.3307	27	1.0630	3	0.120
TP-M-80	80	3.1496	81	3.1890	115	4.5276	31	1.2205	3	0.120
TP-M-85	85	3.3465	86	3.3858	125	4.9213	34	1.3386	3	0.120
TP-M-90	90	3.5433	91	3.5827	135	5.3150	36	1.4173	3	0.120
TP-M-95	95	3.7402	96	3.7795	140	5.5118	38	1.4961	3	0.120
TP-M-100	100	3.9370	101	3.9764	150	5.9055	38	1.4961	3	0.120
TP-M-105	105	4.1339	106	4.1732	155	6.1024	40	1.5748	3	0.120
TP-M-110	110	4.3307	111	4.3701	160	6.2992	40	1.5748	3	0.120

SINGLE-DIRECTION, FLAT-FACE TYPE
HEAVY SERIES, METRIC SIZES

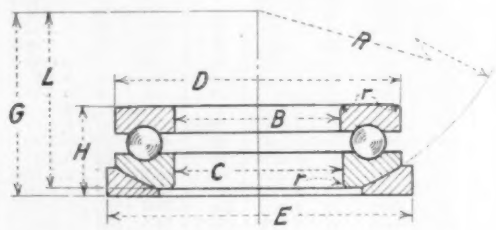
Bearing Number	Inside Diameter (B)		Diameter (C)		Outside Diameter (D)		Height (H)		Chamfer or Radius (r)	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TP-H-25	25	0.9843	26	1.0236	52	2.0472	16	0.6299	2	0.080
TP-H-30	30	1.1811	31	1.2205	60	2.3622	19	0.7480	2	0.080
TP-H-35	35	1.3780	36	1.4173	68	2.6672	22	0.8661	2	0.080
TP-H-40	40	1.5748	41	1.6142	76	2.9921	25	0.9843	2	0.080
TP-H-45	45	1.7717	46	1.8110	85	3.3465	28	1.1024	2	0.080
TP-H-50	50	1.9685	51	2.0079	92	3.6221	31	1.2205	2	0.080
TP-H-55	55	2.1654	56	2.2047	100	3.9370	33	1.2992	3	0.120
TP-H-60	60	2.3622	61	2.4016	106	4.1732	35	1.3780	3	0.120
TP-H-65	65	2.5591	66	2.5984	112	4.4095	36	1.4173	3	0.120
TP-H-70	70	2.7559	71	2.7953	120	4.7244	38	1.4961	3	0.120
TP-H-75	75	2.9528	76	2.9921	128	5.0394	41	1.6142	3	0.120
TP-H-80	80	3.1496	81	3.1890	136	5.3543	44	1.7323	3	0.120
TP-H-85	85	3.3465	86	3.3858	145	5.7087	47	1.8504	3	0.120
TP-H-90	90	3.5433	91	3.5827	155	6.1024	50	1.9685	3	0.120
TP-H-95	95	3.7402	96	3.7795	165	6.4961	54	2.1260	3	0.120
TP-H-100	100	3.9370	101	3.9764	172	6.7717	57	2.2441	3	0.120
TP-H-105	105	4.1339	106	4.1732	180	7.0866	60	2.3622	3	0.120
TP-H-110	110	4.3307	111	4.3701	190	7.4803	63	2.4803	3	0.120



DOUBLE-DIRECTION, FLAT-FACE TYPE LIGHT SERIES, METRIC SIZES

Bearing Number	Inside Diameter (A)		Diameter (C)		Outside Diameter (D)		Height (H)		Thickness of Central Washer (S)	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTP-L-10	10	0.3937	16	0.6299	31	1.2205	22	0.8861	6.0	0.2362
DTP-L-12	12	0.4724	18	0.7087	35	1.3780	22	0.8861	6.0	0.2362
DTP-L-15	15	0.5906	21	0.8268	37	1.4567	22	0.8861	6.0	0.2362
DTP-L-20	20	0.7874	26	1.0236	45	1.7717	26	1.0236	7.0	0.2756
DTP-L-25	25	0.9843	31	1.2205	50	1.9685	26	1.0236	7.0	0.2756
DTP-L-30	30	1.1811	41	1.6142	60	2.3622	29	1.1417	7.5	0.2953
DTP-L-35	35	1.3780	46	1.8110	68	2.6672	29	1.1417	7.5	0.2953
DTP-L-40	40	1.5748	51	2.0079	74	2.9134	32	1.2598	8.0	0.3150
DTP-L-45	45	1.7717	56	2.2047	78	3.0709	32	1.2598	8.0	0.3150
DTP-L-50	50	1.9685	61	2.4016	82	3.2284	32	1.2598	8.0	0.3150
DTP-L-55	55	2.1654	66	2.5984	90	3.5433	36	1.4173	9.0	0.3543
DTP-L-60	60	2.3622	71	2.7953	95	3.7402	36	1.4173	9.0	0.3543
DTP-L-65	65	2.5591	76	2.9921	100	3.9370	36	1.4173	9.0	0.3543
DTP-L-70	70	2.7559	81	3.1890	110	4.3307	40	1.5748	10.5	0.4134
DTP-L-75	75	2.9528	86	3.3858	115	4.5276	40	1.5748	10.5	0.4134
DTP-L-80	80	3.1496	91	3.5827	120	4.7244	40	1.5748	10.5	0.4134
DTP-L-85	85	3.3465	96	3.7795	130	5.1181	45	1.7717	11.0	0.4331
DTP-L-90	90	3.5433	101	3.9764	135	5.3150	45	1.7717	11.0	0.4331
DTP-L-95	95	3.7402	106	4.1732	140	5.5118	45	1.7717	11.0	0.4331
DTP-L-100	100	3.9370	111	4.3701	145	5.7087	45	1.7717	11.0	0.4331

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.



DOUBLE-DIRECTION, FLAT-FACE TYPE MEDIUM SERIES, METRIC SIZES

Bearing Number	Inside Diameter (A)		Diameter (C)		Outside Diameter (D)		Height (H)		Thickness of Central Washer (S)	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTP-L-10	10	0.3937	16	0.6299	35	1.3780	26	1.0236	7.0	0.2756
DTP-L-15	15	0.5906	21	0.8268	40	1.5748	26	1.0236	7.0	0.2756
DTP-L-20	20	0.7874	26	1.0236	48	1.8898	28	1.1024	7.0	0.2756
DTP-L-25	25	0.9843	31	1.2205	53	2.0866	28	1.1024	7.0	0.2756
DTP-L-30	30	1.1811	41	1.6142	64	2.5197	32	1.2598	7.5	0.2953
DTP-L-35	35	1.3780	46	1.8110	73	2.8740	36	1.4173	8.0	0.3150
DTP-L-40	40	1.5748	51	2.0079	78	3.0709	36	1.4173	8.0	0.3150
DTP-L-45	45	1.7717	56	2.2047	88	3.4646	42	1.6535	9.0	0.3543
DTP-L-50	50	1.9685	61	2.4016	90	3.5433	42	1.6535	9.0	0.3543
DTP-L-55	55	2.1654	66	2.5984	100	3.9370	48	1.8898	11.0	0.4331
DTP-L-60	60	2.3622	71	2.7953	103	4.0551	48	1.8898	11.0	0.4331
DTP-L-65	65	2.5591	76	2.9921	110	4.3307	52	2.0472	15.0	0.5906
DTP-L-70	70	2.7559	81	3.1890	115	4.5276	56	2.2047	15.0	0.5906
DTP-L-75	75	2.9528	86	3.3858	125	4.9213	62	2.4409	15.0	0.5906
DTP-L-80	80	3.1496	91	3.5827	135	5.3150	64	2.5197	15.0	0.5906
DTP-L-85	85	3.3465	96	3.7795	140	5.5118	68	2.6672	16.0	0.6299
DTP-L-90	90	3.5433	101	3.9764	150	5.9055	68	2.6672	16.0	0.6299
DTP-L-95	95	3.7402	106	4.1732	155	6.1024	72	2.8346	17.0	0.6693
DTP-L-100	100	3.9370	111	4.3701	160	6.2992	72	2.8346	17.0	0.6693
DTP-L-105	105	4.1339	116	4.5669	165	6.4961	78	3.0709	18.0	0.7087
DTP-L-110	110	4.3307	126	4.9606	175	6.8898	82	3.2284	18.0	0.7087

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.

DOUBLE-DIRECTION, FLAT-FACE TYPE HEAVY SERIES, METRIC SIZES

Bearing Number	Inside Diameter (A)		Diameter (C)		Outside Diameter (D)		Height (H)		Thickness of Central Washer (S)	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTP-H-15	15	0.5906	26	1.0236	52	2.0472	29	1.1417	6	0.2362
DTP-H-20	20	0.7874	31	1.2205	60	2.3622	35	1.3780	8	0.3150
DTP-H-25	25	0.9843	36	1.4173	68	2.6672	40	1.5748	9	0.3543
DTP-H-30	30	1.1811	41	1.6142	76	2.9921	46	1.8110	10	0.3937
DTP-H-35	35	1.3780	46	1.8110	85	3.3465	52	2.0472	12	0.4724
DTP-H-40	40	1.5748	51	2.0079	92	3.6221	57	2.2441	13	0.5118
DTP-H-45	45	1.7717	61	2.4016	106	4.1732	65	2.5591	15	0.5906
DTP-H-50	50	1.9685	66	2.5984	112	4.4095	67	2.6378	16	0.6299
DTP-H-55	55	2.1654	71	2.7953	120	4.7244	71	2.7953	17	0.6693
DTP-H-60	60	2.3622	76	2.9921	128	5.0394	76	2.9921	18	0.7087
DTP-H-65	65	2.5591	81	3.1890	136	5.3543	81	3.1890	19	0.7480
DTP-H-70	70	2.7559	86	3.3858	145	5.7087	87	3.4252	20	0.7874
DTP-H-75	75	2.9528	91	3.5827	155	6.1024	92	3.6221	21	0.8268
DTP-H-80	80	3.1496	96	3.7795	165	6.4961	98	3.8583	22	0.8661
DTP-H-85	85	3.3465	106	4.1732	180	7.0866	109	4.2913	24	0.9449
DTP-H-90	90	3.5433	111	4.3701	190	7.4803	115	4.5276	25	0.9843
DTP-H-95	95	3.7402	116	4.5669	200	7.8740	120	4.7244	26	1.0236
DTP-H-100	100	3.9370	121	4.7638	210	8.2677	125	4.9213	27	1.0630
DTP-H-110	110	4.3307	131	5.1575	220	8.6614	131	5.1575	32	1.2598

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.

SINGLE-DIRECTION, SELF-ALIGNING TYPE LIGHT SERIES, METRIC SIZES

Bearing Number	Inside Diameter (B)		Diameter (C)		Outside Diameter (D)		Diameter (E)		Height (H)		Radius (R)		L		G	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TS-L-10	10	0.3937	12	0.4724	26	1.0236	30	1.1811	13.5	0.5315	20	0.7874	17.86	0.7032	19.36	0.7622
TS-L-12	12	0.4724	14	0.5512	28	1.1024	32	1.2598	14.5	0.5709	20	0.7874	17.32	0.6819	19.82	0.7803
TS-L-15	15	0.5906	17	0.6693	31	1.2205	35	1.3780	14.5	0.5709	25	0.9843	22.20	0.8740	23.70	0.9331
TS-L-17	17	0.6693	19	0.7480	35	1.3780	37	1.4567	14.5	0.5709	25	0.9843	21.65	0.8524	23.15	0.9114
TS-L-20	20	0.7874	22	0.8661	37	1.4567	40	1.5748	15.0	0.5906	30	1.1811	26.53	1.0445	28.53	1.1232
TS-L-25	25	0.9843	27	1.0630	45	1.7717	48	1.8898	17.0	0.6693	35	1.3780	30.31	1.1933	32.31	1.2721
TS-L-30	30	1.1811	32	1.2598	50	1.9685	53	2.0866	17.0	0.6693	40	1.5748	34.64	1.3638	36.64	1.4425
TS-L-35	35	1.3780	37	1.4567	55	2.1654	60	2.3622	19.0	0.7480	45	1.7717	38.98	1.5346	40.98	1.6134
TS-L-40	40	1.5748	42	1.6535	60	2.3622	65	2.5591	19.0	0.7480	50	1.9685	43.30	1.7047	45.30	1.7835
TS-L-45	45	1.7717	47	1.8504	68	2.6672	72	2.8346	19.0	0.7480	55	2.1654	47.34	1.8638	49.34	1.9425
TS-L-50	50	1.9685	52	2.0472	74	2.9134	78	3.0709	21.0	0.8268	60	2.3622	51.37	2.0224	53.37	2.1012
TS-L-55	55	2.1654	57	2.2441	78	3.0709	82	3.2284	21.5	0.8465	65	2.5591	56.00	2.2047	58.50	2.3032
TS-L-60	60	2.3622	62	2.4409	82	3.2284	86	3.3858	21.5	0.8465	70	2.7559	60.33	2.3752	62.82	2.4732
TS-L-65	65	2.5591	67	2.6378	90	3.5433	95	3.7402	24.5	0.9646	75	2.9528	64.36	2.5339	66.86	2.6323
TS-L-70	70	2.7559	72	2.8346	95	3.7402	100	3.9370	24.5	0.9646	80	3.1496	68.69	2.7043	71.19	2.8028
TS-L-75	75	2.9528	77	3.0315	100	3.9370	105	4.1339	25.0	0.9843	85	3.3465	73.03	2.8752	76.03	2.9933
TS-L-80	80	3.1496	82	3.2284	110	4.3307	115	4.5276	26.0	1.0236	95	3.7402	82.27	3.2390	85.27	3.3571
TS-L-85	85	3.3465	87	3.4252	115	4.5276	120	4.7244	27.0	1.0630	100	3.9370	86.60	3.4095	89.60	3.5276
TS-L-90	90	3.5433	92	3.6221	120	4.7244	125	4.9213	27.0	1.0630	105	4.1339	90.93	3.5799	93.93	3.6980
TS-L-95	95	3.7402	97	3.8189	130	5.1181	135	5.3150	30.0	1.1811	110	4.3307	94.68	3.7276	97.68	3.8457
TS-L-100	100	3.9370	102	4.0157	135	5.3150	140	5.5118	30.0	1.1811	115	4.5276	99.01	3.8980	102.01	4.0161
TS-L-105	105	4.1339	107	4.2126	140	5.5118	145	5.7087	30.0	1.1811	120	4.7244	103.34	4.0685	106.34	4.1866
TS-L-110	110	4.3307	112	4.4095	145	5.7087	150	5.9055	30.0	1.1811	125	4.9213	107.67	4.2390	110.67	4.3571

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.

SINGLE-DIRECTION, SELF-ALIGNING TYPE MEDIUM SERIES, METRIC SIZES

Bearing Number	Inside Diameter (B)		Diameter (C)		Outside Diameter (D)		Diameter (E)		Height (H)		Radius (R)		L		G	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TS-M-10	10	0.3937	12	0.4724	30	1.1811	35	1.3780	16	0.6299	20	0.7874	17.02	0.6701	19.02	0.7488
TS-M-12	12	0.4724	14	0.5512	32	1.2598	37	1.4567	16	0.6299	22	0.8661	19.05	0.7500	21.05	0.8287
TS-M-15	15	0.5906	17	0.6693	35	1.3780	40	1.5748	18	0.7087	25	0.9843	21.03	0.8280	23.93	0.9421
TS-M-17	17	0.6693	19	0.7480	38	1.4961	42	1.6535	18	0.7087	27	1.0630	23.93	0.9421	25.93	1.0209
TS-M-20	20	0.7874	22	0.8661	40	1.5748	45	1.7717	18	0.7087	30	1.1811	27.04	1.0646	29.04	1.1433
TS-M-25	25	0.9843	27	1.0630	48	1.8898	50	1.9685	19	0.7480	35	1.3780	30.87	1.2114	33.87	1.3335
TS-M-30	30	1.1811	32	1.2598	53	2.0866	60	2.3622	21	0.8268	40	1.5748	35.20	1.3858	38.20	1.5039
TS-M-35	35	1.3780	37	1.4567	62	2.4409	70	2.7559	24	0.9449	50	1.9685	44.90	1.7677	47.90	1.8858
TS-M-40	40	1.5748	42	1.6535	64	2.5197	72	2.8346	24	0.9449	50	1.9685	43.59	1.7161	46.59	1.8343
TS-M-45	45	1.7717	47	1.8504	73	2.8740	80	3.1496	28	1.1024	60	2.3622	53.32	2.0992	56.32	2.2173
TS-M-50	50	1.9685	52	2.0472	78	3.0709	85	3.3465	28	1.1024	65	2.5591	57.66	2.2701	60.66	2.3882
TS-M-55	55	2.1654	57	2.2441	88	3.4646	95	3.7402	32	1.2598	70	2.7559	62.00	2.4339	66.00	2.5984
TS-M-60	60	2.3622	62	2.4409	90	3.5433	100	3.9370	32	1.2598	75	2.9528	66.33	2.6114	70.33	2.7689
TS-M-65	65	2.5591	67	2.6378	100	3.9370	110	4.3307	36	1.4173	80	3.1496	70.67	2.7823	74.67	2.9398
TS-M-70	70	2.7559	72	2.8346	103	4.0551	115	4.5276	36	1.4173	85	3.3465	74.67	2.9398	78.67	3.0972
TS-M-75	75	2.9528	77	3.0315	110	4.3307	120	4.7244	36	1.4173	90	3.5433	79.33	3.1232	83.33	3.2807
TS-M-80	80	3.1496	82	3.2284	115	4.5276	125	4.9213	39	1.5354	95	3.7402	83.67	3.2941	87.67	3.4516
TS-M-85	85	3.3465	87	3.4252	125	4.9213	135	5.3150	42	1.6535	105	4.1339	93.64	3.6866	97.64	3.8441
TS-M-90	90	3.5433	92	3.6221	135	5.3150	140	5.5118	43	1.6929	110	4.3307	97.20	3.8268	101.20	3.9843
TS-M-95	95	3.7402	97	3.8189	140	5.5118	150	5.9055	45	1.7717	115	4.5276	101.27	3.9870	105.27	4.1445
TS-M-100	100	3.9370	102	4.0157	150	5.9055	160	6.2992	46	1.8110	120	4.7244	104.49	4.1138	108.49	4.2713
TS-M-105	105	4.1339	107	4.2126	155	6.1024	165	6.4961	48	1.8898	130	5.1181	112.58	4.4323	117.58	4.6291
TS-M-110	110	4.3307	112	4.4095	160	6.2992	170	6.6929	48	1.8898	135	5.3150	116.91	4.6028	121.91	4.7996

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.

SINGLE-DIRECTION, SELF-ALIGNING TYPE HEAVY SERIES, METRIC SIZES

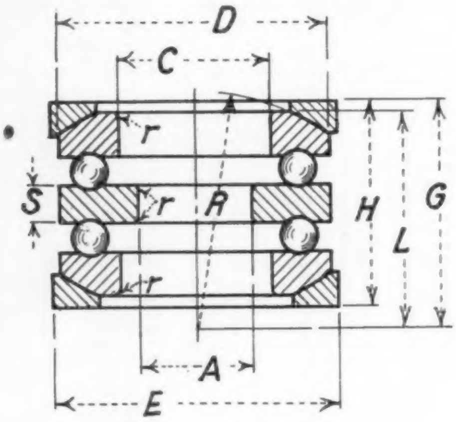
Bearing Number	Inside Diameter (B)		Diameter (C)		Outside Diameter (D)		Diameter (E)		Height (H)		Radius (R)		L		G	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
TS-H-25	25	0.9843	27	1.0630	52	2.0472	55	2.1654	22	0.8661	40	1.5748	34.64	1.3638	37.64	1.4819
TS-H-30	30	1.1811	32	1.2598	60	2.3622	65	2.5591	24	0.9449	45	1.7717	38.97	1.5343	41.97	1.6524
TS-H-35	35	1.3780	37	1.4567	68	2.6672	75	2.9528	27	1.0630	55	2.1654	47.63	1.8752	50.63	1.9933
TS-H-40	40	1.5748	42	1.6535	76	2.9921	85	3.3465	30	1.1811	60	2.3622	51.96	2.0457	54.96	2.1638
TS-H-45	45	1.7717	47	1.8504	85	3.3465	95	3.7402	33	1.2992	65	2.5591	56.29	2.2161	59.29	2.3343
TS-H-50	50	1.9685	52	2.0472	92	3.6221	100	3.9370	36	1.4173	75	2.9528	64.95	2.5571	67.95	2.6752
TS-H-55	55	2.1654	57	2.2441	100	3.9370	110	4.3307	39	1.5354	80	3.1496	69.28	2.7276	73.28	2.8850
TS-H-60	60	2.3622	62	2.4409	106	4.1732	115	4.5276	41	1.6142	85	3.3465	73.61	2.8980	77.61	3.0555
TS-H-65	65	2.5591	67	2.6378	112	4.4095	120	4.7244	42	1.6535	90	3.5433	77.94	3.0685	81.94	3.2260
TS-H-70	70	2.7559	72	2.8346	120	4.7244	130	5.1181	44	1.7323	95	3.7402	82.27	3.2390	86.27	3.3965
TS-H-75	75	2.9528	77	3.0315	128	5.0394	140	5.5118	47	1.8504	105	4.1339	90.93	3.5799	94.93	3.7374
TS-H-80	80	3.1496	82	3.2284	136	5.3543	145	5.7087	50	1.9685	110	4.3307	95.26	3.7504	99.26	3.9879
TS-H-85	85	3.3465	87	3.4252	145	5.7087	155	6.1024	54	2.1260	120	4.7244	103.92	4.0913	108.92	4.2882
TS-H-90	90	3.5433	92	3.6221	155	6.1024	165	6.4961	57	2.2441	125	4.9213	108.25	4.2618	113.25	4.4587
TS-H-95	95	3.7402	97	3.8189	165	6.4961	175	6.8898	61	2.4016	130	5.1181	112.68	4.4362	117.68	4.6331
TS-H-100	100	3.9370	102	4.0157	172	6.7717	185	7.2835	64	2.5197	140	5.5118	121.24	4.7732	126.24	4.9701
TS-H-105	105	4.1339	107	4.2126	180	7.0866	195	7.6772	67	2.6378	145	5.7087	125.57	4.9437	130.57	5.1406
TS-H-110	110	4.3307	112	4.4095	190	7.4803	205	8.0709	70	2.7559	155	6.1024	134.23	5.2847	139.23	5.4815

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.

DOUBLE-DIRECTION, SELF-ALIGNING TYPE LIGHT SERIES, METRIC SIZES

Bearing Number	Inside Diameter (A)		Diameter (C)		Outside Diameter (D)		Diameter (E)		Height (H)		Thickness of Central Washer (S)		Radius (R)		L		G	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTS-L-10	10	0.3937	17	0.6693	31	1.2205	35	1.3780	27	1.0630	6.0	0.2362	25	0.9843	22.20	0.8740	23.70	0.9331
DTS-L-12	12	0.4724	19	0.7480	35	1.3780	37	1.4567	27	1.0630	6.0	0.2362	25	0.9843	21.65	0.8524	23.15	0.9114
DTS-L-15	15	0.5906	22	0.8661	37	1.4567	40	1.5748	28	1.1024	6.0	0.2362	30	1.1811	26.53	1.0445	28.53	1.1232
DTS-L-20	20	0.7874	27	1.0630	45	1.7717	48	1.8898	32	1.2598	7.0	0.2756	35	1.3780	30.31	1.1933	32.31	1.2721
DTS-L-25	25	0.9843	32	1.2598	50	1.9685	53	2.0866	32	1.2598	7.0	0.2756	40	1.5748	34.64	1.3638	36.64	1.4425
DTS-L-30	30	1.1811	42	1.6535	60	2.3622	65	2.5591	35	1.3780	7.5	0.2953	50	1.9685	43.30	1.7047	45.30	1.7835
DTS-L-35	35	1.3780	47	1.8504	68	2.6672	72	2.8346	35	1.3780	7.5	0.2953	55	2.1654	47.34	1.8638	49.34	1.9425
DTS-L-40	40	1.5748	52	2.0472	74	2.9134	78	3.0709	38	1.4961	8.0	0.3150	60	2.3622	51.37	2.0224	53.37	2.1012
DTS-L-45	45	1.7717	57	2.2441	78	3.0709	82	3.2284	39	1.5354	8.0	0.3150	65	2.5591	56.00	2.2047	58.50	2.3032
DTS-L-50	50	1.9685	62	2.4409	82	3.2284	86	3.3858	39	1.5354	8.0	0.3150	70	2.7559	60.33	2.3752	62.82	2.4732
DTS-L-55	55	2.1654	67	2.6378	90	3.5433	95	3.7402	45	1.7717	9.0	0.3543	75	2.9528	64.36	2.5339	66.86	2.6323
DTS-L-60	60	2.3622	72	2.8346	95	3.7402	100	3.9370	45	1.7717	9.0	0.3543	80	3.1496	68.69	2.7043	71.19	2.8028
DTS-L-65	65	2.5591	77	3.0315	100	3.9370	105	4.1339	46	1.8110	9.0	0.3543	85	3.3465	73.03	2.8752	76.03	2.9933
DTS-L-70	70	2.7559	82	3.2284	110	4.3307	115	4.5276	50	1.9685	10.5	0.4134	95	3.7402	82.27	3.2390	85.27	3.3571
DTS-L-75	75	2.9528	87	3.4252	115	4.5276	120	4.7244	50	1.9685	10.5	0.4134	100	3.9370	86.60	3.4095	89.60	3.5276
DTS-L-80	80	3.1496	92	3.6221	120	4.7244	125	4.9213	50	1.9685	10.5	0.4134	105	4.1339	90.93	3.5799	93.93	3.6980
DTS-L-85	85	3.3465	97	3.8189	130	5.1181	135	5.3150	55	2.1654	11.0	0.4331	110	4.3307	94.68	3.7276	97.68	3.8457
DTS-L-90	90	3.5433	102	4.0157	135	5.3150	140	5.5118	55	2.1654	11.0	0.4331	115	4.5276	99.01	3.8980	102.01	4.0161
DTS-L-95	95	3.7402	107	4.2126	140	5.5118	145	5.7087	55	2.1654	11.0	0.4331	120	4.7244	103.34	4.0685	106.34	4.1866
DTS-L-100	100	3.9370	112	4.4095	145	5.7087	150	5.9055	55	2.1654	11.0	0.4331	125	4.9213	107.67	4.2390	110.67	4.3571

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.



DOUBLE-DIRECTION, SELF-ALIGNING TYPE MEDIUM SERIES, METRIC SIZES

Bearing Number	Inside Diameter (A)		Diameter (C)		Outside Diameter (D)		Diameter (E)		Height (H)		Thickness of Central Washer (S)		Radius (R)		L		G	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTS-M-10	10	0.3937	17	0.6693	35	1.3780	40	1.5748	34	1.3386	7.0	0.2756	25	0.9843	21.93	0.8634	23.93	0.9421
DTS-M-15	15	0.5906	22	0.8661	40	1.5748	45	1.7717	34	1.3386	7.0	0.2756	30	1.1811	27.04	1.0646	29.04	1.1433
DTS-M-20	20	0.7874	27	1.0630	48	1.8898	50	1.9685	36	1.4173	7.0	0.2756	35	1.3780	30.87	1.2154	33.87	1.3335
DTS-M-25	25	0.9843	32	1.2598	53	2.0866	60	2.3622	39	1.5354	7.0	0.2756	40	1.5748	35.20	1.3858	38.20	1.5039
DTS-M-30	30	1.1811	42	1.6535	64	2.5197	72	2.8346	44	1.7323	7.5	0.2953	50	1.9685	43.59	1.7161	46.59	1.8343
DTS-M-35	35	1.3780	47	1.8504	73	2.8740	80	3.1496	52	2.0472	8.0	0.3150	60	2.3622	53.32	2.0992	56.32	2.2173
DTS-M-40	40	1.5748	52	2.0472	78	3.0709	85	3.3465	52	2.0472	8.0	0.3150	65	2.5591	57.66	2.2701	60.66	2.3882
DTS-M-45	45	1.7717	57	2.2441	88	3.4646	95	3.7402	58	2.2835	9.0	0.3543	70	2.7559	62.00	2.4409	66.00	2.5984
DTS-M-50	50	1.9685	62	2.4409	90	3.5433	100	3.9370	58	2.2835	9.0	0.3543	75	2.9528	66.33	2.6114	70.33	2.7689
DTS-M-55	55	2.1654	67	2.6378	100	3.9370	110	4.3307	66	2.5984	11.0	0.4331	80	3.1496	70.67	2.7823	74.67	2.9398
DTS-M-60	60	2.3622	72	2.8346	103	4.0551	115	4.5276	66	2.5984	11.0	0.4331	85	3.3465	74.67	2.9398	78.67	3.0972
DTS-M-65	65	2.5591	77	3.0315	110	4.3307	120	4.7244	70	2.7559	15.0	0.5906	90	3.5433	79.33	3.1232	83.33	3.2807
DTS-M-70	70	2.7559	82	3.2284	115	4.5276	125	4.9213	72	2.8346	15.0	0.5906	95	3.7402	83.67	3.2941	87.67	3.4516
DTS-M-75	75	2.9528	87	3.4252	125	4.9213	135	5.3150	78	3.0709	15.0	0.5906	105	4.1339	93.64	3.6866	97.64	3.8441
DTS-M-80	80	3.1496	92	3.6221	135	5.3150	140	5.5118	78	3.0709	15.0	0.5906	110	4.3307	97.20	3.8268	101.20	3.9843
DTS-M-85	85	3.3465	97	3.8189	140	5.5118	150	5.9055	82	3.2284	16.0	0.6299	115	4.5276	101.27	3.9870	105.27	4.1445
DTS-M-90	90	3.5433	102	4.0157	150	5.9055	160	6.2992	84	3.3071	16.0	0.6299	120	4.7244	104.49	4.1138	108.49	4.2713
DTS-M-95	95	3.7402	107	4.2126	155	6.1024	165	6.4961	88	3.4646	17.0	0.6693	130	5.1181	112.58	4.4323	117.58	4.6291
DTS-M-100	100	3.9370	112	4.4095	160	6.2992	170	6.6929	88	3.4646	17.0	0.6693	135	5.3150	116.91	4.6028	121.91	4.7996
DTS-M-105	105	4.1339	117	4.6063	165	6.4961	175	6.8898	92	3.6221	18.0	0.7087	140	5.5118	121.65	4.7894	126.65	4.9862
DTS-M-110	110	4.3307	122	4.8032	175	6.8898	190	7.4803	100	3.9370	18.0	0.7087	150	5.9055	130.00	5.1181	136.00	5.3543

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.

DOUBLE-DIRECTION, SELF-ALIGNING TYPE HEAVY SERIES, METRIC SIZES

Bearing Number	Inside Diameter (A)		Diameter (C)		Outside Diameter (D)		Diameter (E)		Height (H)		Thickness of Central Washer (S)		Radius (R)		L		G	
	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.
DTS-H-15	15	0.5906	27	1.0630	52	2.0472	55	2.1654	41	1.6142	6	0.2362	40	1.5748	34.64	1.3638	37.64	1.4819
DTS-H-20	20	0.7874	32	1.2598	60	2.3622	65	2.5591	45	1.7717	8	0.3150	45	1.7717	38.97	1.5343	41.97	1.6524
DTS-H-25	25	0.9843	37	1.4567	68	2.6672	75	2.9528	50	1.9685	9	0.3543	55	2.1654	47.63	1.8752	50.63	1.9933
DTS-H-30	30	1.1811	42	1.6535	76	2.9921	85	3.3465	56	2.2047	10	0.3937	60	2.3622	51.96	2.0457	54.96	2.1638
DTS-H-35	35	1.3780	47	1.8504	85	3.3465	95	3.7402	62	2.4409	12	0.4724	65	2.5591	56.29	2.2161	59.29	2.3343
DTS-H-40	40	1.5748	52	2.0472	92	3.6221	100	3.9370	67	2.6378	13	0.5118	75	2.9528	64.95	2.5567	67.95	2.6748
DTS-H-45	45	1.7717	62	2.4409	106	4.1732	115	4.5276	77	3.0315	15	0.5906	85	3.3465	73.61	2.8980	77.61	3.0551
DTS-H-50	50	1.9685	67	2.6378	112	4.4095	120	4.7244	79	3.1102	16	0.6299	90	3.5433	77.94	3.0685	81.94	3.2260
DTS-H-55	55	2.1654	72	2.8346	120	4.7244	130	5.1181	83	3.2677	17	0.6693	95	3.7402	82.27	3.2390	86.27	3.3965
DTS-H-60	60	2.3622	77	3.0315	128	5.0394	140	5.5118	88	3.4646	18	0.7087	105	4.1339	90.93	3.5799	94.93	3.7374
DTS-H-65	65	2.5591	82	3.2284	136	5.3543	145	5.7087	93	3.6614	19	0.7480	110	4.3307	95.26	3.7504	99.26	3.9079
DTS-H-70	70	2.7559	87	3.4252	145	5.7087	155	6.1024	101	3.9764	20	0.7874	120	4.7244	103.92	4.0913	108.92	4.2882
DTS-H-75	75	2.9528	92	3.6221	155	6.1024	165	6.4961	106	4.1732	21	0.8268	125	4.9213	108.25	4.2618	113.25	4.4587
DTS-H-80	80	3.1496	97	3.8189	165	6.4961	175	6.8898	112	4.4095	22	0.8661	130	5.1181	112.68	4.4362	117.68	4.6331
DTS-H-85	85	3.3465	107	4.2126	180	7.0866	195	7.6772	123	4.8425	24	0.9449	145	5.7087	125.57	4.9437	130.57	4.1406
DTS-H-90	90	3.5433	112	4.4095	190	7.4803	205	8.0709	129	5.0787	25	0.9843	155	5.1024	134.23	5.2847	139.23	4.4815
DTS-H-95	95	3.7402	117	4.6063	200	7.8740	215	8.4646	136	5.3543	26	1.0236	160	6.2992	138.56	5.4551	142.56	5.5732
DTS-H-100	100	3.9370	122	4.8032	210	8.2677	225	8.8583	143	5.6299	27	1.0630	170	6.6929	147.23	5.7965	153.23	6.0327
DTS-H-110	110	4.3307	132	5.1969	220	8.6614	235	9.2520	148	5.8268	32	1.2598	175	6.8898	151.55	5.9665	155.55	6.1240

The same chamfers or corner radii specified for the single-direction, flat-face type thrust ball bearings apply to this series.

the practice of at least six domestic manufacturers using this type of bearing and that it is necessary to consider European practice as the importance of international standardization cannot be overlooked.

MINORITY REPORT

The boundary dimensions, principally the inside and outside diameters, of some of the proposed metric-type thrust ball-bearings standards are such that if the proper ball-diameters are used, or those consistent with the size of the bearing, there is not a sufficient difference between the diameter of the ball and the width of the face of the bearing to permit the use of a ball retainer of sufficient strength to give satisfactory service.

It was suggested at the Subdivision meeting in New York City on Nov. 9 that smaller ball sizes might be used in certain bearing sizes to permit the use of a satisfactory retainer. While this is possible, the recommendations should be along the lines of good engineering and not recommend substitutes.

It was stated at the Subdivision meeting that the present demand for metric thrust ball-bearings represents only a very small percentage of the total demand for thrust bearings. Any action taken toward the standardization of an unknown quantity should certainly be considered in the light of past experience. It was also stated that certain of the proposed metric sizes have been made with retainers having either the inside or outside section, that part extending beyond the ball, cut away entirely so as to keep the bearing within the boundary dimensions referred to. It is not considered that this represents good ball-bearing practice.

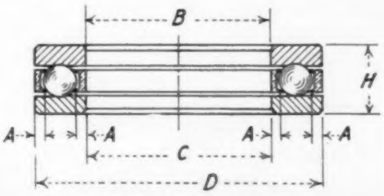
The demand for metric sizes apparently dates back to certain requirements during the war period that could not be taken care of by the importation of metric-type thrust ball-bearings. Keeping in mind that the Society of Automotive Engineers is representative of the American automotive industries whose output represents about 87 per cent of the world's production of automobiles, it is improbable that the demand arose in this Country. In view of these figures it is reasonable to assume that the European manufacturers would adopt our standards if they were properly presented.

The adoption of the report proposed at the Subdivision meeting held on Nov. 9 means that we are surrendering our American standard practice to that of European manufacturers.

We, the undersigned, therefore urge that this matter be given serious consideration and recommend that it be referred back to the Ball and Roller Bearings Division with instructions to submit a recommendation on the same general line of standardization of inch-type thrust-bearings, or redesign the present proposed metric sizes along the lines of the best engineering practice including the ball diameters.

The accompanying data are submitted in support of the above statements.

(Signed) Frank Beemer
S. A. Strickland
F. A. Collins, Jr.



CAGE DIMENSIONS ALLOWED BY PROPOSED S. A. E. STANDARD FOR SINGLE-DIRECTION, FLAT-FACE TYPE THRUST BALL-BEARINGS

Inside Diameter (B)		Diameter (C)		Outside Diameter (D)		Height		Ball Diameter	A*
Mm.	In.	Mm.	In.	Mm.	In.	Mm.	In.	In.	In.
25	0.9843	26	1.0236	45	1.7717	14	0.5512	9/32	0.0460
30	1.1811	31	1.2205	50	1.9686	14	0.5512	9/32	0.0460
35	1.3780	36	1.4173	55	2.1654	16	0.6299	5/16	0.0310
40	1.5748	41	1.6142	60	2.3622	16	0.6299	5/16	0.0310
60	2.3622	61	2.4016	82	3.2284	18	0.7087	11/32	0.0340
65	2.5591	66	2.5984	90	3.5433	20	0.7874	3/8	0.0480
70	2.7559	71	2.7953	95	3.7402	20	0.7874	3/8	0.0480

*Dimension A permits a clearance of 1 mm. on the inside diameter of the retainer when mounted on a shaft of diameter B. Dimension A does not make an allowance for the necessary clearance about the balls and a clearance between the outside diameters of retainer and bearing.

ELECTRIC VEHICLE DIVISION REPORT

Division Personnel

E. L. Clark, *Chairman*	Commercial Truck Co.
Karl Probst, *Vice-Chairman*	Milburn Wagon Co.
G. L. Bixby	Detroit Electric Car Co.
J. G. Carroll	Walker Vehicle Co.
H. M. Pierce	Ward Motor Vehicle Co.
F. E. Queeney	Lansden Co., Inc.
C. R. Skinner, Jr.	New York Edison Co.

ELECTRIC VEHICLE MOTORS

(Proposed S.A.E. Recommended Practice)

At the last meeting of the Electric Vehicle Division it was thought that a definite standard for the rating of vehicle motors would be of great advantage in comparing tests of motors of various makes and the adoption of the method of rating motors approved by the American Institute of Electrical Engineers was favored, provided a 4-hr. time limit and a normal load were specified when rating the motor. Therefore

The Electric Vehicle Division recommends the adoption as S.A.E. Recommended Practice for the following rating for electric vehicle motors.

The rating of electric automobile propulsion motors shall be based on a temperature rise not to exceed 65 deg. cent. (149 deg. fahr.) by thermometer, or 75 deg. cent. (167 deg. fahr.) by resistance after 4 hr. of continuous operation at normal rated load

The tests shall be made on a stand with a constant room-temperature of 20 deg. cent. (68 deg. fahr.) and with the motor covers arranged as in service.

With the exception of the time limit and rated load requirements, this rating conforms to Section 5205 of the 1921 A. I. E. E. Standardization Rules.

ELECTRICAL EQUIPMENT DIVISION REPORT

Division Personnel

F. W. Andrew, *Chairman*	Eisemann Magneto Corporation
T. L. Lee, *Vice-Chairman*	North East Electric Co.
Azel Ames	Kerite Insulated Wire & Cable Co.
G. S. Cawthorne	Master Trucks, Inc.
W. A. Chryst	Dayton Engineering Laboratories Co.
S. F. Evelyn	Continental Motors Corporation
C. F. Gilchrist	Electric Auto-Lite Corporation
W. S. Haggott	Packard Electric Co.
C. H. Kindl	Westinghouse Electric & Mfg. Co.
F. C. Kroeger	Remy Electric Co.
B. M. Leece	Leece-Neville Co.
A. D. T. Libby	Splitdorf Electrical Co.
Charles Marcus	Bijur Motor Appliance Co.
Ernest Wooler	Cleveland Automobile Co.

In 1920 the Electrical Equipment Division appointed a Subdivision to review the present S.A.E. Standards for generator and starting-motor mountings and to bring them into accord with the best engineering practice. A general letter was sent out to generator and starting-motor users requesting suggestions as to possible re-

visions of the present S.A.E. Standards, the suggestions received being referred to the Subdivision of which T. L. Lee, of the North East Electric Co., was chairman, the other members being C. H. Kindl, of the Westinghouse Electric & Mfg. Co., Ernest Wooler, of the Cleveland Automobile Co., B. M. Leece, of the Leece-Neville Co., and S. F. Evelyn, of the Continental Motors Corporation.

Several meetings of the Subdivision were held at which the present standards were considered and tentative revisions drafted. A joint meeting with the Automotive Electric Association was also held at White Sulphur Springs in June, largely for the purpose of securing more effective results through closer cooperation of the Society and that organization with the executives of the consuming interests.

The recommendations of the Subdivision were submitted to generator and starting-motor manufacturers and users and, as they met with general approval, they were approved by the Electrical Equipment Division.

It is therefore felt that the recommendations covering the present S.A.E. Standards will meet the objections which have been raised and have prevented the more extensive use of these important standards.

GENERATOR FLANGE MOUNTINGS

(Proposed Revision of S.A.E. Standard)

As considerable trouble has been experienced in using the present S.A.E. Standard Generator Flange Mountings, p. B17 of the S.A.E. HANDBOOK, due to the cotter-pin hole being located too close to the end of the shaft and as it is considered desirable to use S.A.E. Standard lock-washers and nuts for holding the gear on the shaft-end, revisions of dimensions *L* and *M* were proposed.

The Subdivision has also been advised that in some generator installations a gasket is frequently used under the flange, which is not completely dimensioned in the present standard. The Subdivision has therefore proposed additional contour dimensions and a maximum flange-thickness of ½ in. to complete the standard. It was also thought advisable by the Division that the detailed dimensions of the shaft-end be specified. Therefore

The Electrical Equipment Division recommends that the present S.A.E. Standard for Generator Flange Mountings, p. B17 of the S.A.E. HANDBOOK, be revised by

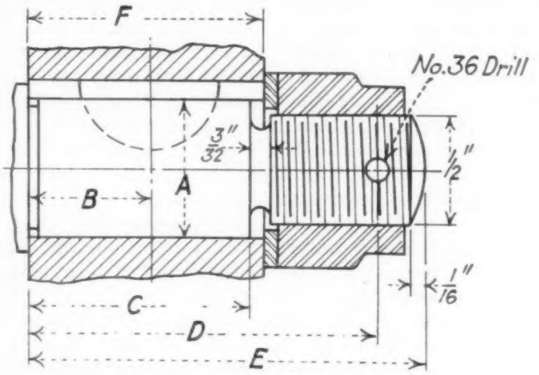
Increasing dimension *D* by 1/32 in. and dimension *E* by 3/32 in.

The addition of the ⅞-in. and 1½-in. contour dimensions.

The addition of a flange thickness of ½ in.

The addition of the detailed shaft-end dimensions.

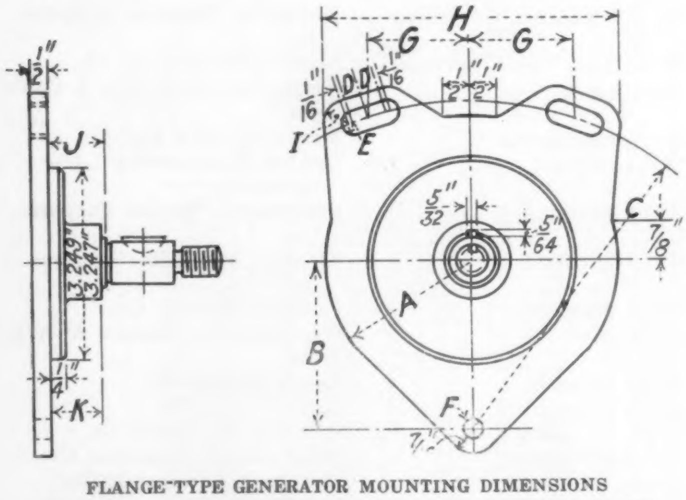
The present S.A.E. Standard revised as proposed by the Electrical Equipment Division is given in the accompanying tables.



FLANGE-TYPE GENERATOR SHAFT-END DIMENSIONS

Size No.	Diameter A		Woodruff Key		C	D	E	F
	Max.	Min.	Key No.	B				
1	0.6250	0.6245	6	3/16	1	1 3/16	1 11/32	1 1/16
2	0.7500	0.7495	8	11/16	1¼	1 11/16	2 1/32	1 1/16

The pinion shall be held on by a 33/64 x 1/16-in. S.A.E. Special Light lock-washer and a ½ in.-20 S.A.E. Standard castellated nut.



FLANGE-TYPE GENERATOR MOUNTING DIMENSIONS

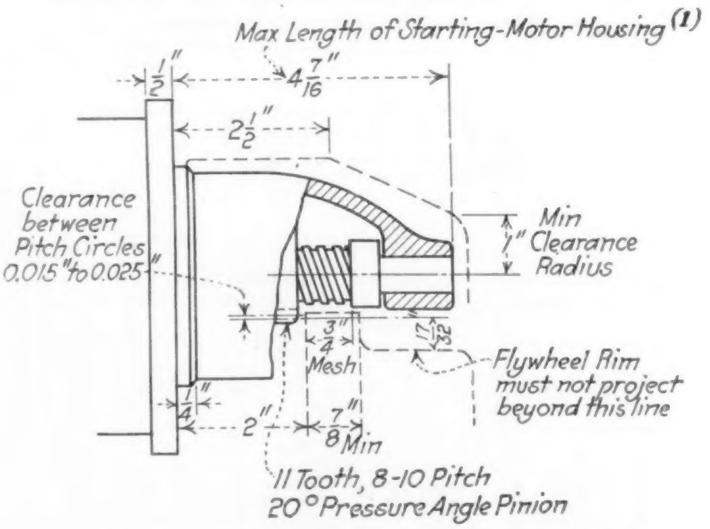
Size No.	A	B	C	D	E	F	G	H Max.	I	J ± 1/64	K Max.
1	2⅜	2 11/16	5⅜	¼	7/32	11/32	1⅝	4¾	7/16	13/16	¾
2	2⅝	3 1/16	5⅞	5/16	¼	15/32	1 13/16	5⅝	½	1 1/16	1

STARTING-MOTOR FLANGE MOUNTINGS

OUTBOARD TYPE

(Proposed S.A.E. Recommended Practice)

As the Subdivision on Generator and Starting-Motor Mountings considered that the present S.A.E. Standard for Starting-Motor Flange Mountings, p. B19 of the S.A.E. HANDBOOK, should be amplified by a type of



OUTBOARD-TYPE STARTING-MOTOR FLANGE MOUNTINGS

In special cases where 13-tooth large-shift pinions are required, the maximum length of the starting-motor housing shall be 4¾ instead of 4 7/16 in. and the flywheel mesh 1 instead of ¾ in.

The flange dimensions shall be the same as those specified for the present S.A.E. Standard for Inboard-Type Starting-Motor Flange Mountings, p. B19 of the S.A.E. HANDBOOK.

mounting for outboard installations only, a recommendation for this type of flange mounting similar to the present recommended practice for starting-motor barrel mountings of the outboard type was submitted to and favorably considered by the Division. Therefore

> The Electrical Equipment Division recommends for adoption as S.A.E. Recommended Practice the outboard-type starting-motor flange dimensions given in the accompanying illustration [see p. 536].

INBOARD TYPE

(Proposed Revision of S.A.E. Standard)

As it is necessary in some installations to attach the starting motor to the flywheel housing by the use of studs instead of bolts because of insufficient clearance, it was suggested that the Electrical Equipment Division should specify the thickness of the starting-motor flange in order that the length of the studs might be readily determined. This matter was favorably considered by the Subdivision on Generator and Starting-Motor Mountings, and subsequently by the Division. Therefore

> The Electrical Equipment Division recommends that the present S.A.E. Standard for Starting-Motor Flange Mountings, p. B19 of the S.A.E. HANDBOOK, be extended by specifying a ½-in. flange thickness.

STARTING-MOTOR PINIONS

(Proposed Revision of S.A.E. Recommended Practice)

As the present S.A.E. Recommended Practice for Starting-Motor Pinions, p. B18 of the S.A.E. HANDBOOK, has been misinterpreted to some extent since the last revision in wording was made in March, 1921, the Electrical Equipment Division has given careful consideration to rewording this recommendation. Although it is recognized that with the involute form of tooth the pitch-lines do not exist until the gears are mounted in their running positions, it is thought that the theoretical pitch-circle about which the teeth are generated may be considered as distinct from the running pitch-circles. Therefore

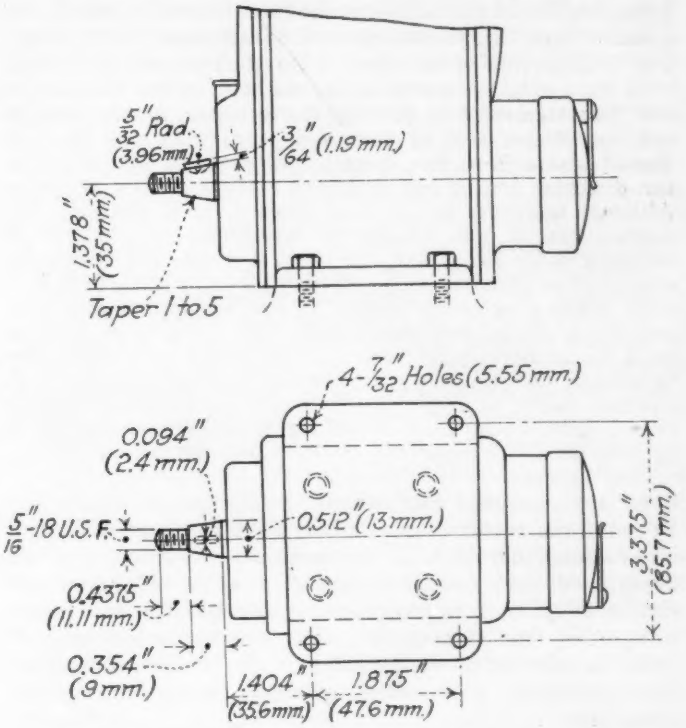
> The Electrical Equipment Division recommends that the present S.A.E. Recommended Practice for Starting-Motor Pinions, p. B18 of the S.A.E. HANDBOOK be revised to read, "Flywheel starting-motors shall be equipped with an 8-10 pitch, 11-tooth, 20-deg. pressure-angle pinion and be installed so that the pitch-circle about which the teeth of the pinion are generated will be separated from 0.015 to 0.025 in. from the pitch-circle about which the teeth on the flywheel are generated."

MAGNETO MOUNTINGS

(Proposed S.A.E. Standard)

Subsequent to the adoption in August of the S.A.E. Recommended Practice for the stationary-engine base-type magneto mounting, the Electrical Equipment Division was asked to consider the standardization of a flange type of mounting for installation where it is impossible to use the base type.

A review of the stationary-engine magneto situation indicated that such a standard mounting should be provided, and the Subdivision on magneto mountings was reappointed, with A. D. T. Libby, of the Splitdorf Electrical Co., chairman. At the October meeting of the Division Mr. Libby submitted a report covering a recommendation for this type of magneto, which is used primarily on one and two-cylinder stationary engines, the height from the base to the center-line of the shaft-end and the shaft-end dimensions being the same as the



dimensions specified in the present recommended practice, p. B16 of the S.A.E. HANDBOOK. The recommendation is in accord with magneto dimensions used extensively in this Country for the past 4 or 5 years. Therefore

> The Electrical Equipment Division recommends for adoption as S.A.E. Recommended Practice the flange type of stationary-engine magneto mounting shown in the accompanying illustration.

SPARK-PLUGS

(Proposed Revision of S.A.E. Standard)

The present S.A.E. Standard for Spark-Plug Shells specifies ⅞ and 1⅛-in. widths across flats and does not include the dimensions for various types of terminal. As it was felt that it would be possible to standardize on certain types of terminal and to revise the standards so as to eliminate all but those dimensions necessary to permit interchangeability, a Subdivision was appointed to review the spark-plug standards and to formulate a report to the Electrical Equipment Division. The Subdivision appointed was as follows:

O. C. Rohde, *Chairman*	Champion Spark Plug Co.
D. L. Arnold	
B. M. deGuichard	A. C. Spark-Plug Co.
A. D. T. Libby	Splitdorf Electric Co.
C. S. Price	Bethlehem Spark-Plug Co.
M. J. Steele	Packard Motor Car Co.
L. M. Woolson	Packard Motor Car Co.

At a Subdivision meeting held in August it was stated that two-thirds of the spark-plugs manufactured at the present time have a ½-in. pipe thread, but that the general objection to pipe threads for spark-plugs is the difficulty of accurately maintaining the distance that the spark-plug screws into the cylinder; that metric spark-plugs are used only to a limited extent; that spark-plugs with ¾-in. pipe threads are being gradually discontinued, as are also the 5/16 and ⅜-in. spark-plugs with pipe threads; and that the majority of spark-plugs exclusive of the sizes mentioned are made with the S.A.E. Standard spark-plug thread of ⅞ in. –18. It was there-

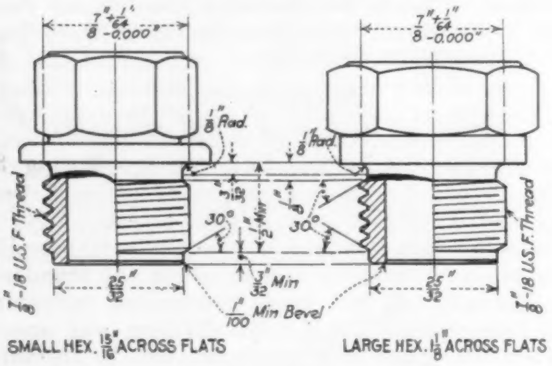
fore considered advisable by the Subdivision to retain the present standard thread as well as all dimensions affecting that portion of the spark-plug shell below the gasket.

In discussing the width across the flats of the hexagon or the "hex diameter" as it is generally called, it was brought out that 20 per cent of the spark-plugs with a ⅞-in. —18 thread have a ⅞-in. hex diameter, 20 per cent have a 1⅛-in. hex diameter and 60 per cent have a 15/16-in. hex diameter. Although there are two or three large users of the ⅞-in. hex spark-plugs, it was considered inadvisable to continue to recommend the use of this size because it does not leave sufficient wall to stand up under wrench strain, especially in two-piece spark-plug construction. It was recognized that it is possible to design two-piece spark-plugs for a ⅞-in. hex but as it would necessitate special inside parts that would not be used on the standard one-piece spark-plug, expensive tool-changes would be required. It would be, however, possible for machinery now used in making ⅞-in.-hex spark-plugs to be reset so as to make the 15/16-in.-hex without additional tooling expense.

At a subsequent meeting of the Electrical Equipment Division the report of the Subdivision was approved after careful consideration of the problems involved. It was recognized that the proposals of the Subdivision could not be adopted in present practice by certain automobile companies, but it was felt that the revised standards could be adopted at some future time by such companies simultaneously with other changes in engine design. Therefore

> The Electrical Equipment Division recommends that the present S.A.E. Standard for Automobile Spark-Plug Shells, p. A10 of the S.A.E. HANDBOOK, be superseded by the following proposed S.A.E. Standard for Inch-Type Spark-Plugs.

INCH-TYPE SPARK-PLUGS



The spark-plug shell dimensions shall conform to those specified in the accompanying illustration for the 15/16 and 1⅛-in. hexagon spark-plugs respectively. All dimensions below the shoulder shall be identical for both sizes of spark-plug.

The outside diameter shall be 0.8750 in. and the number of threads per inch shall be 18. The limits for the pitch-diameter shall be 0.8389 in. maximum and 0.8348 in. minimum for the spark-plug threads and 0.8430 in. maximum and 0.8389 in. minimum for the tapped-hole threads.

SPARK-PLUG TERMINALS

Threaded Type.—The terminal thread shall be No. 8-32 (0.164 in. diameter) S.A.E. Coarse Thread

Ball Type.—For the ball type of spark-plug terminal the ball diameter shall be 13/32 in.

Slip-Type.—For the slip type of spark-plug terminal the ball diameter shall be 13/32 in. and shall have a groove width of 0.043 in. plus 0.006 minus 0.000 and a groove diameter of 0.203 in. plus 0.015 minus 0.000

Post Type.—For the post type of spark-plug terminal the large diameter of the taper post shall be 0.250 in. plus 0.000 and minus 0.003 and the neck diameter 0.220 in. plus 0.000 and minus 0.008

ENGINE DIVISION REPORT

Division Personnel

J. B. Fisher, *Chairman*	Waukesha Motor Co.
R. J. Broege, *Vice-Chairman*	Buda Co.
P. J. Dasey	Midwest Engine Corporation
S. F. Evelyn	Continental Motors Corporation
E. J. Hall	Hall-Scott Motor Co.
H. B. Massey	Holmes Automobile Co.
A. F. Milbrath	Wisconsin Motor Mfg. Co.
Louis Schwitzer	Automotive Parts Co.
M. J. Steele	Packard Motor Car Co.

FLYWHEEL HOUSINGS

(Proposed Revision of S.A.E. Standard)

Owing to the number of negative votes which were cast against the adoption of the Engine Division recommendation that the clearance space for crankshaft flywheel bolts should have a minimum diameter of 6½ in. and a minimum depth of ¾ in. in view of the general criticism that the recommendation was too limiting on clutch design, the Council referred the recommendation back to the Engine Division for joint consideration with the Transmission Division. The following conference Subdivision was therefore appointed: Messrs. Wemp and Copland representing the Transmission Division and Messrs. Evelyn and Steele the Engine Division:

E. E. Wemp, *Chairman*	Long Mfg. Co.
A. W. Copland	Detroit Gear Machine Co.
S. F. Evelyn	Continental Motors Corporation
F. J. Steele	Packard Motor Car Co.

A meeting of the Subdivision was held in Detroit on Oct. 24 and a report adopted which was submitted at subsequent meetings of the Engine and Transmission Divisions, the recommendation meeting with favorable consideration. The following is extracted from the Subdivision report.

> An analysis of present practice indicates that the flywheel bolt clearance of small and medium-size engines comes well within the present standard of 6⅛ in., this dimension being equaled or exceeded only on engines of high torque capacity.
>
> This condition will probably continue since it is to the engine builder's advantage from a cost standpoint to keep the flywheel bolt-circle diameter as small as possible, and as long as this is done the clutch manufacturer should have no difficulty in adapting his product to the engine. Insofar as the single-plate type of clutch is concerned, it is believed that the larger size of clutch required will provide for the necessary clearance space without difficulty.
>
> With regard to the multiple-disc type, the Subdivision believes it is important to establish a maximum dimension from the flywheel face to the ends of the flywheel bolts so as to provide a clearance between the flywheel bolts and the driven member of the clutch.
>
> Since ½-in. diameter crankshaft-bolts are used to such a large extent for this purpose, the Subdivision recommends a maximum dimension of 11/16 in. from the flywheel face to the ends of the flywheel bolts. This will allow the bolt to project ⅛ in. through a ½-in. castellated nut, or will easily take care of a ½-in. plain nut and a heavy lock-washer.
>
> The Subdivision believes that until it is possible to standardize the actual crankshaft bolt-circle diameter the present clearance space of 6⅛ in. should be eliminated as being confusing and of no practical value. Therefore

The Engine Division recommends that the present S.A.E. Standard for Flywheel Housings, p. A1 of the S.A.E. HANDBOOK, reading, "The minimum diameter of the clearance space for crankshaft flywheel bolt-nuts shall be 6⅛ in. and the minimum depth ⅝ in.," should be omitted and the following substituted, "The maximum dimension from the flywheel face to the ends of the crankshaft flywheel bolts shall be 11/16 in."

FRAMES DIVISION REPORT

Division Personnel

E. V. Rippingille, *Chairman*	Watson Stabilator Co.
L. J. Fralick, *Vice-Chairman*	Hydraulic Steel Co.
C. C. Bowman	Standard Motor Truck Co.
E. A. DeWaters	Buick Motor Co.
O. B. Harmon	Parish & Bingham Co.
W. A. McKinley	Detroit Pressed Steel Co.
D. G. Roos	Locomobile Co.
C. W. Wright	A. O. Smith Corporation

RUNNING-BOARD BRACKETS

(Proposed Extension of S.A.E. Recommended Practice)

The present S.A.E. Recommended Practice for Running-Board Brackets, p. H23 of the S.A.E. HANDBOOK, was approved by the Society in March, 1922. Several negative votes were cast, however, because the gage of the stock was not specified, another variable thus being introduced in the recommended practice.

The Frames Division at a meeting in September reviewed this subject and felt that a definite gage-thickness would make the recommended practice more complete. Therefore

The Frames Division recommends that the present S.A.E. Recommended Practice for Running-Board Brackets, p. H23 of the S.A.E. HANDBOOK, be extended by the addition of a note reading, "The thickness of stock shall be 5/32 in. (0.156 in. or No. 9 U. S. gage).

IRON AND STEEL DIVISION REPORT

Division Personnel

F. P. Gilligan, *Chairman*	Henry Souther Engineering Corporation
W. C. Peterson, *Vice-Chairman*	Atlas Steel Corporation
R. M. Bird	Bethlehem Steel Co.
H. T. Chandler	C. H. Wills & Co.
A. L. Colby	Consulting Metallurgist
L. A. Danse	Cadillac Motor Car Co.
C. N. Dawe	Studebaker Corporation of America
B. H. DeLong	Carpenter Steel Co.
A. P. Eves	International Harvester Co.
H. L. Greene	Willys-Overland Co.
C. G. Heilman	General Motors Corporation
E. J. Janitzky	Illinois Steel Co.
J. B. Johnson	Air Service
F. C. Langenberg	Watertown Arsenal
A. H. Miller	Midvale Steel & Ordnance Co.
C. S. Moody	Minneapolis Steel & Machinery Co.
J. H. Nelson	Wyman-Gordon Co.
G. L. Norris	Vanadium Corporation of America
W. H. Phillips	R. D. Nuttall Co.
S. P. Rockwell	Consulting Metallurgist
M. P. Rumney	Detroit Steel Products Co.
C. F. W. Rys	Carnegie Steel Co.
R. B. Schenck	Buick Motor Co.
M. H. Schmid	United Alloy Steel Corporation
H. J. Stagg	Halcomb Steel Co.
J. M. Watson	Hupp Motor Car Corporation
J. H. G. Williams	Billings & Spencer

IRON AND STEEL SPECIFICATIONS

(Proposed Revision of S.A.E. Standard)

As a result of several proposals for the standardization of additional steel compositions, action was taken at the last meeting of the Iron and Steel Division adopting a policy of not including a new composition in the S.A.E. Standard for Iron and Steel Specifications unless it is shown that there is a sufficient tonnage of the steel used to warrant such action. Therefore, the Division felt that a statement should be included in the published report of the Iron and Steel Division to the effect that steels having different ranges of carbon than those specified in the present S.A.E. Standard are obtainable from the mills.

The Iron and Steel Division recommends that the present S.A.E. Standard for Iron and Steel Specifications be amplified by the inclusion of the following sentence in the first paragraph of Part I, p. D1 of the S.A.E. HANDBOOK, "The standard chemical compositions are for steels used by the automotive industry in large quantities, but other compositions having different ranges of carbon are obtainable from the mills."

In March 1922 the Society adopted the revised and extended report of the Iron and Steel Division covering the chemical compositions of the various iron and steel specifications. At that time the maximum sulphur-content recommended for S.A.E. Steel 3115 was 0.040 per cent, the maximum sulphur-content for the other steels of the 3100 series being 0.045 per cent. At the October meeting of the Division it was pointed out that there is no particular reason for not having the maximum sulphur-content the same for all the steels of the 3100 series. Therefore

The Iron and Steel Division recommends that the present S.A.E. Standard for Iron and Steel Specifications, Part III—Chemical Compositions, p. D4 of the S.A.E. HANDBOOK, be revised so as to specify a maximum sulphur-content of 0.045 instead of 0.040 per cent for S.A.E. Steel 3115.

LIGHTING DIVISION REPORT

Division Personnel

W. A. McKay, *Chairman*	Westinghouse Lamp Co.
C. A. Michel, *Vice-Chairman*	Guide Motor Lamp Mfg. Co.
J. T. Caldwell	National Lamp Works
C. E. Godley	Edmunds & Jones Corporation
C. A. B. Halvorson, Jr.	General Electric Co.
L. C. Porter	Edison Lamp Works
E. S. Preston	Chicago Electric Mfg. Co.
C. D. Ryder	Corcoran-Victor Co.
J. C. Stearns	Culver-Stearns Mfg. Co.
T. I. Walker	Providence Base Works
E. E. Wood	Miniature Incandescent Lamp Corporation
Ernest Wooler	Cleveland Automobile Co.

ELECTRIC INCANDESCENT LAMPS

(Proposed Revision of S.A.E. Standard)

The Society has adopted head-lamp illumination specifications requiring the use of 21-cp. electric incandescent lamps and, as this candlepower is required by law in many of the States having head-lamp regulations, it was felt at the last meeting of the Lighting Division that the present S.A.E. Standard for Electric Incandescent Lamps should be extended to specify this candlepower. Therefore

The Lighting Division recommends that the present S.A.E. Standard for Electric Incandescent Lamps, p. B3 of the S.A.E. HANDBOOK, should be amplified by the addition of a footnote reading, "Incandescent lamps for automobile head-lamps shall be of the gas-filled type and of 21 cp."

LUBRICANTS DIVISION

Division Personnel

H. C. Mougey, *Chairman*	General Motors Research Corporation
W. E. Jominy, *Vice-Chairman*	Studebaker Corporation of America

CRANKCASE LUBRICATING OILS

General.—These specifications cover grades of petroleum oil for the lubrication of internal-combustion engines, except aircraft, and are not recommended for the lubrication of turbines.

Compounded lubricating oils containing products other than those derived from petroleum are not dealt with in these specifications.

Specification No.[2]	Explanatory Grade Names	Flash-Point, Deg. Fahr., Min.	Fire-Point, Deg. Fahr., Min.	Viscosity, Saybolt Sec.				Dilution with Water-White Kerosene for No. 5 N.P.A. Color		Pour Test, Deg. Fahr., Max.	Conradson Carbon Residue, Per Cent, Max.	Corrosion Test
				100 Deg. Fahr.		210 Deg. Fahr.						
				Min.	Max.	Min.	Max.	Parts, Kerosene	Parts, Oil			
20	Light	325	365	180	220	42	...	50	50	35	0.20	Required for all grades
020	Light	325	365	180	220	42	...	50	50	10	0.20	
30	Medium	335	380	270	330	44	...	50	50	40	0.30	
030	Medium	335	380	270	330	44	...	50	50	10	0.30	
40	Medium	345	390	360	440	46	...	60	40	45	0.40	
50	Heavy	355	400	450	575	50	...	70	30	50	0.60	
60	Heavy	360	...	...	...	55	65	80	20	55	0.80	
80	Extra Heavy	380	...	...	...	75	85	85	15	55	1.50	
95	Extra Heavy	390	...	...	...	90	100	90	10	55	1.75	
115	Extra Heavy	400	...	...	...	110	120	95	5	60	2.00	

[2]For Specifications Nos. 20 to 50, inclusive, the numbers indicate the first two figures of the average Saybolt viscosity in seconds at 100 deg. fahr. for the grades indicated. The first cipher in Specifications Nos. 020 and 030 indicates that the pour-test value of these two grades is 10 deg. fahr. The numbers for Specifications Nos. 60 to 115, inclusive, indicate the average Saybolt viscosity in seconds at 210 deg. fahr.

Corrosion Test.—The following corrosion test shall not cause discoloration of copper strip. Place a clean piece of mechanically polished pure strip-copper about ½ in. wide and 3 in. long, and 10 cc. of the oil to be tested, in a clean test-tube. Close the tube with a vented stopper and hold for 3 hr. at 212 deg. fahr. Rinse the copper strip with sulphur-free acetone and compare it with a similar strip of freshly polished copper.

Sydney Bevin	Tide Water Oil Co.
P. J. Dasey	Midwest Engine Corporation
A. P. Eves	International Harvester Co.
W. H. Herschel	Bureau of Standards
K. G. Mackenzie	Texas Co.
W. E. Perdew	Union Petroleum Co.
W. D. Reese, Jr.	Fifth Ave. Coach Co.
H. G. Smith	Formerly with Atlantic Refining Co.
J. W. Stack	Standard Oil Co.

CRANKCASE LUBRICATING OILS
(Proposed S.A.E. Standard)

In 1912 the Society adopted a specification known as No. 26 for pure mineral automobile engine light lubricating oil. This specification proved satisfactory for a number of years as applying to paraffin-base oils. In April, 1920, at the request of the Tractor Division, the Lubricants Division prepared to make a careful study of the requirements for more extensive standard lubricating oil specifications. The basis for this work was Bulletin No. 4, dated April, 1920, issued by the Bureau of Mines. The Lubricants Division attended several meetings of the Government petroleum fuel committees and in November 1921 submitted a tentative specification based partly on the work of the Government and partly on information obtained through a questionnaire sent out by the Division. The comments on the tentative specification were considered and a revised proposal published in the June 1922 issue of THE JOURNAL for discussion at the Standards Committee meeting at White Sulphur Springs. Subsequent to this consideration of the report, a number of tests of five unknown kinds of oil were made by members of the Division, the samples being identified only by numbers. The results of these tests indicated the necessity for recognizing the difficulties in securing uniform results throughout the industry in checking oils to the proposed specifications. The limiting values in the specification were readjusted accordingly and the revised report published in the November 1922 issue of THE JOURNAL, one of the important points in the report being the classification of the grades of oils by numbers indicating the viscosity characteristics of the respective grades.

There were a number of differences between the proposed specification and those issued by the Interdepartmental Committee of the Government on Petroleum Specifications and arrangements were accordingly made for a joint conference of the Society's Lubricants Division, the Advisory Committee on Petroleum Specifications of the American Petroleum Institute and the Interdepartmental Committee in Washington on Nov. 13 to secure uniformity in the specifications. The various points were thoroughly discussed and informally acted upon, following which the members of the Division voted to submit the following specifications for adoption as S.A.E. Standard for internal-combustion engine lubricating oils as it was felt that the Society should adopt such specifications as soon as possible. The chairman of the Interdepartmental Committee stated at the conference that his committee could not take formal action at that time, but would probably meet early in February to consider the points under discussion in connection with the revised specification of the Society and the Governmental specifications. Therefore

The Lubricants Division recommends the adoption of the accompanying specification as S.A.E. Standard.

NOMENCLATURE DIVISION REPORT

Division Personnel

H. L. Pope, *Chairman*	Wright Aeronautical Corporation
W. P. Kennedy, *Vice-Chairman*	Kennedy Engineering Corporation

J. B. Bartholomew	Avery Co.
W. F. Borgerd	International Harvester Co.
W. S. Bouton	Hendee Mfg. Co.
W. J. Brandon	Avery Co.
H. R. Cobleigh	National Automobile Chamber of Commerce
W. P. Culver	American Auto Parts Co.
A. B. Cumner	Autocar Co.
L. S. Keilholtz	Delco-Light Co.
V. E. McMullen	Hercules Gas Engine Co.
Leonard Ochtman, Jr.	Joseph Van Blerck, Inc.
W. T. Thomas	Thomas-Morse Aircraft Corporation
J. G. Vincent	Packard Motor Car Co.
L. C. Voyles	Nordyke & Marmon Co.

Automobile Nomenclature

(Proposed Revision of S.A.E. Standard)

The function of the Nomenclature Division in the standardization of automotive nomenclature is primarily to unify and correlate nomenclatures worked out by other Divisions of the Standards Committee, and to arrange them properly in the present S.A.E. Standard for Automobile Nomenclature, p. K1 of the S.A.E. Handbook.

The present nomenclature of differential gears in Division XII, Group 4, on p. K15 of the S.A.E. Handbook, is considered obsolete because of the developments in differential design. The Axle and Wheels Division therefore appointed the following Subdivision on Differentials to revise this part of the present standard.

S. O. White, *Chairman*	Warner Gear Co.
F. E. McMullen	Gleason Works
D. D. Ormsby	Brown-Lipe-Chapin Co.

Mr. White was also a member of a similar committee appointed by the American Gear Manufacturers Association, that considered and approved the report of the Subdivision prior to its final consideration by the Axle and Wheels Division. Therefore

> The Nomenclature Division recommends that the following nomenclature be adopted as a revision of the present differential nomenclature, Division XII, Group 4 of the present S.A.E. Standard for automobile nomenclature.

Differential Nomenclature

FOUR-PINION TWO-PIECE CASE BEVEL DRIVE

Differential[3]
Bevel-Drive Pinion[4]
Bevel-Drive Gear
Differential Case Flange Half
Differential Case Plain Half
Differential Bearing Sleeve
Differential Case Bolt
Bevel-Drive Gear Rivet or Screw
Differential Side Gear
Differential Spider Pinion
Differential Spider

TWO-PINION ONE-PIECE CASE BEVEL DRIVE

Differential[3]
Bevel-Drive Pinion[4]
Bevel-Drive Gear
Differential Case
Differential Bearing Sleeve
Bevel-Drive Gear Rivet or Screw
Differential Side Gear
Differential Cross-Pin Pinion
Differential Cross Pin
Differential Cross-Pin Lock
Differential Side Gear Spacer

[3] *Differential.*—A differential comprises a case and internal parts only.

[4] *Bevel-Drive Pinion or Worm.*—A bevel-drive pinion or worm may be of either the "bored" or the "shaft" type.

WORM-GEAR DRIVE

Differential[3]
Worm[4]
Worm Gear
Differential Case, right hand
Differential Case, left hand
Differential Bearing Sleeve
Differential Case Bolt
Worm-Gear Rivet or Screw
Differential Side Gear
Differential Pinion
Differential Spider or Cross Pin
Differential Cross-Pin Lock
Differential Side Gear Spacer

PARTS AND FITTINGS DIVISION REPORT

Division Personnel

F. G. Whittington, *Chairman*	Stewart-Warner Speedometer Corporation
W. C. Keys, *Vice-Chairman*	Gabriel Mfg. Co.
Clarence Carson	Dodge Bros.
E. R. Douglas	Formerly with Cincinnati Ball Crank Co.
H. B. Garman	Garman Mfg. Co.
H. S. Jandus	C. G. Spring Co.
F. W. Slack	Peerless Motor Car Co.
C. W. Spicer	Spicer Mfg. Corporation
Alex Taub	General Motors Corporation
E. W. Weaver	Weaver & Kemble Co.

Plain Washers

(Proposed S. A. E. Standard)

In August, 1922, the Society adopted the report of the Parts and Fittings Division covering Plain Washers for S.A.E. Standard bolts. The Division has continued this standardization to include plain washers for machine screws in order that the standards for screws, bolts and nuts, lock-washers and plain washers may be complete. Therefore

> The Parts and Fittings Division recommends that the present S.A.E. Standard for Plain Washers, p. C5c of the S.A.E. Handbook, be extended to include the dimensions for washers used with screws below 1/4 in. diameter as given in the accompanying table. As the material used for the proposed washers may be other than steel, it is also recommended that the title of the present standard be changed to "Plain Washers."

The present S.A.E. Standard for Plain Washers is given also in the accompanying table.

PROPOSED S. A. E. STANDARD DIMENSIONS FOR PLAIN WASHERS

Screw and Bolt Sizes	Inside Diameter	Outside Diameter	Thickness ±0.010
2	3/32	1/4	1/32
4	1/8	5/16	1/32
6	5/32	3/8	3/64
8	3/16	7/16	3/64
10	7/32	1/2	1/16
12	1/4	9/16	1/16
1/4	9/32	5/8	1/16
5/16	11/32	11/16	1/16
3/8	13/32	13/16	1/16
7/16	15/32	15/16	1/16
1/2	17/32	1 1/16	3/32
9/16	19/32	1 3/16	3/32
5/8	21/32	1 5/16	3/32
11/16	23/32	1 3/8	3/32
3/4	13/16	1 1/2	1/8
7/8	15/16	1 3/4	1/8
1	1 1/16	2	1/8
1 1/8	1 3/16	2 1/4	1/8
1 1/4	1 5/16	2 1/2	5/32
1 3/8	1 7/16	2 3/4	5/32
1 1/2	1 9/16	3	5/32

All dimensions in inches. Washers shall be flat and free from burrs.

ROD-ENDS

(Proposed Revision of S.A.E. Standard)

The present S.A.E. Standard for Rod-Ends, p. C8 of the S.A.E. HANDBOOK, specified a 3/16-in.-32 thread for the smallest size of the light series rod-end, whereas the S.A.E. Standard for Ball-and-Socket Joints, p. C52, specified a No. 10-32 thread for the corresponding size. As generally accepted standards for screws, bolts, nuts and similar threaded parts are made in numbered or decimal sizes below ¼ in., instead of in fractional sizes, and as it should be possible to use the same thread at both ends of a rod when used with a ball-and-socket joint at one end and an adjustable rod-end at the other,

The Parts and Fittings Division recommends that the present S.A.E. Standard for Rod-ends, p. C8 of the S.A.E. HANDBOOK, be revised to specify a No. 10-32 in place of the 3/16-in.-32 thread for the smallest size of the light-rod-end series.

PASSENGER-CAR BODY DIVISION REPORT

Division Personnel

G. E. Goddard, *Chairman*	Dodge Bros.
A. J. Neerken, *Vice-Chairman*	Hupp Motor Car Corporation
S. J. Baum	Brewster & Co.
E. G. Budd	Edward G. Budd Mfg. Co.
J. S. Burdick	Buffalo Body Corporation
O. H. Clark	Zeder-Skelton-Breer Engineering Co.
A. E. Garrels	Studebaker Corporation of America
E. W. Goodwin	Maxwell Motor Corporation
G. W. Kerr	Rolls-Royce of America, Inc.
G. J. Mercer	Consulting Engineer
H. C. Nelson	Mullins Body Corporation

DOOR LOCKS AND HANDLES

(Proposed S.A.E. Recommended Practice)

In March, 1922 the Passenger-Car Body Division report on door-handle squares was approved by the Society. Further discussion of this recommendation at recent meetings of the Division indicated the desirability of specifying the size of the broached hole in the door-handle cam. Data obtained from manufacturers formed the basis for the following recommendation.

The Division has also considered the standardization of door-handle escutcheon plates. The Subdivision that investigated this subject recommended that the center-to-center distance of the two holes and the size of screws should be standardized in accordance with the prevailing practice as given below.

The Division has felt that in many instances door-handle bars are too short and that a sufficient clearance between the handle and the face of the door panel is not allowed. Although this is not considered very important as a standard, it is thought that a recommendation indicating desirable practice would lead to improvements in many designs.

The Division has also considered the various bevels used for door-lock face-plates and believes that a standard will be of value, especially to door-lock manufacturers. An analysis of current production has shown that a large number of angles are used. This subject has been considered also by the Automobile Body Builders' Association, which suggested adopting angles of 6 and 9 deg., that is, included angles of 96 and 99 deg. It was felt, however, that one angle is sufficient for doors for all types of body. Therefore

The Passenger-Car Body Division recommends that the present S.A.E. Recommended Practice for Door-Handles, p. K45 of the S.A.E. HANDBOOK, be extended by the addition of the following recommendations:

(1) No. 10 wood screws 1 in. long shall be used for door-handle escutcheon plates which shall have countersunk holes spaced 1½ in. from center-to-center

(2) The broached hole in door-handle cams on the inside handle shall be 5/16 in. with tolerances of plus or minus 0.001 in.

(3) The included angle of the two sides of door-lock face-plates shall be 96 deg. for doors for all types of body and shall be inspected to gage

(4) Bar-type door-handles shall have a bar at least 3½ in. long and the clearance from the inside of the bar to the face of the door panel shall be not less than 1½ in.

WOOD SCREWS

(Proposed S.A.E. Recommended Practice)

One of the important problems in passenger-car body building is the drilling of holes for wood screws so that the maximum holding power of the screw may be obtained. The specifications formulated by the Federal Specifications Board for wood screws were reviewed by the Passenger-Car Body Division at the October meeting, but it was felt that further simplification than that proposed could be accomplished by limiting the recommendation to the even numbered sizes beginning with the No. 4 size, except the No. 5 size which is used to a large extent. It was considered that the use of wood screws having cut threads should be recommended, as their holding power is greater than that of screws made with rolled threads. Therefore

The Passenger-Car Body Division proposes the following for adoption as S.A.E. Recommended Practice:

(1) Only even number sizes of wood screws commencing with the No. 4 size, with the exception of the No. 5 size, shall be used in automobile body construction. The heads may be either upset or turned, but the slots in the heads shall be milled and the threads cut

(2) The diameter of the drill used shall be the same as the maximum wood-screw diameter at the root of the full thread. All countersunk holes for wood screws shall have an included angle of 82 deg.

PLATE GLASS

(Proposed S.A.E. Recommended Practice)

One of the most important materials entering into body construction is the glass used in windshields and windows, and the need for dimensional specifications thereof was recognized by the Division. A. J. Neerken, who was appointed a Subdivision of one to prepare a tentative recommendation, obtained information from body builders as to the dimensions and grades of glass used and a recommendation was based on this information and specifications were drawn up by the glass manufacturers and users in cooperation with the Bureau of Standards. It is felt that one of the most valuable results of this standardization will be to make possible a clear and undistorted view. The recommendations proposed will be of value to glass users also in drawing up purchasing specifications and lead to the elimination of many odd-size sheets. Therefore the Passenger-Car Body Division recommends that the following proposal be adopted as S.A.E. Recommended Practice.

Glass sizes for windshields and doors shall be selected in increments of even 2 in. The glass producer should be furnished with a templet of the finished glass.

Only polished plate glass shall be used in windshields and front-quarter door windows.

Polished plate glass for windshields and passenger-car windows shall be of two grades: "Selected Glazing" and "Glazing."

"Selected glazing" plate glass shall contain practically no visible imperfections under specified conditions of inspection. Very fine scattered seeds are permissible.

"Glazing" plate glass shall contain no other visible imperfections than a few scattered seeds and occasional faint strings or faint short finish-marks.

The thickness of plate glass shall be 3/16 in. with a tolerance of plus or minus 1/32 in. with variations in individual plates of not more than 1/64 in.

The following definitions of the terms used in the above specifications are taken from the report of the committee on standards of plate glass organized by the Bureau of Standards:

Seeds.—Minute bubbles smaller than 0.015 in. diameter. These are visible only on close inspection, usually appearing as small specks, and are an inherent defect in the best quality of plate glass

Strings.—Light, wavy, transparent lines on the surface, appearing as though a thread of glass had been partially incorporated into the sheet

Short Finish.—Poor polish is lack of smoothness, an improperly finished surface which has the appearance of being slightly pitted and wavy when the surface is viewed by reflected light. These indentations which are slight have a polished surface rather than a ground surface, but the general effect is a slight dulling of the surface. Poor polish is usually caused by improper grinding. Spots on the surface where the fine grinding has not proceeded far enough to produce a smooth surface before polishing will not polish smooth

SCREW-THREADS DIVISION REPORT

Division Personnel

E. H. Ehrman, *Chairman*	Chicago Screw Co.
O. B. Zimmerman, *Vice-Chairman*	International Harvester Co.
Earle Buckingham	Pratt & Whitney Co.
E. Burdsall	Russell, Burdsall & Ward Bolt and Nut Co.
Luther Burlingame	Brown & Sharpe Co.
G. S. Case	Lamson & Sessions Co.
W. R. Mitchell	National Acme Mfg. Co.
Alex Taub	General Motors Corporation

GAGES AND GAGING

(*Proposed General Information*)

The Screw-Threads Division has undertaken to prepare a series of articles covering various phases of screw-thread practice and matters germane thereto for publication as general information in THE JOURNAL and subsequently in the S.A.E. HANDBOOK. The Division submitted an article to the Standards Committee in June on the fundamentals of gages and gaging for screw-thread products, but this report was referred back for amplification with regard to the importance of gaging for lead error. The second and third paragraphs of Section 4 dealing with this phase of the subject have been added. Therefore

The Screw-Threads Division recommends that the following article be approved by the Standards Committee for publication as general information only.

GAGES AND GAGING FOR SCREW-THREADS

I. INTRODUCTORY

The art of measuring screw-threads has developed very rapidly during the past few years. This development still continues, so that it would be extremely inadvisable to attempt to specify any one definite method as standard for this purpose. The object of this report is to establish so far as possible the fundamentals of this subject, and to point out various practices now successfully used.

II. FUNDAMENTALS

Object of Gaging.—The final result sought by gaging is interchangeable manufacture in some degree. This means that the mating parts can be assembled without *fitting* one part to another and, when assembled, the mechanism will function properly. Gaging should be employed more to prevent unsatisfactory parts from being produced than to sort out the correct parts from the incorrect ones.

Direction of Tolerances on Gages.—The extreme sizes for all limit-gages shall never exceed the extreme limits of the part being produced. All variations in the gages, whatever their cause or purpose, shall bring these gages within these extreme limits. Thus a gage that represents a minimum limit may be larger, but never smaller, than the minimum size specified for the part being produced, while the gage that represents a maximum limit may be smaller, but never larger, than the maximum size specified for the part being produced.

Temperature at Which Gages Shall Be Standard.—Gages shall be standard at a temperature of 68 deg. fahr.

Standard or Basic Size.—The standard or basic size, as physically represented by a correct standard master-gage, is the line at which interference begins between mating parts.

Purpose of "Go" and "Not Go" Gages.—The "Go" gages, which are the gages that represent the maximum limit of the internal member and the minimum limit of the external member, control the allowances between mating surfaces and also control interchangeability. "Go" gages control the maximum tightness in the fit of mating parts. Parts that are acceptable to proper "Go" gages will always interchange. Successful interchangeable manufacturing has been carried on for many years with the use of "Go" gages only.

The "Not Go" gages limit the extent of the permissible variations, thus limiting the amount of looseness between mating parts. "Not Go" gages control the maximum looseness in the fit of mating parts and thus control, in large measure, the proper functioning of the assembled mechanisms.

III. GAGE CLASSIFICATION

Master Gage.—The master gage is a plug thread-gage that represents as exactly as possible the physical dimensions of the nominal or basic size of the component. A *standard master-gage* shall be accompanied by a record of its measurement and the gage should be used with knowledge of any deviations or corrections. In case of question, the deviations of this gage from the exact standard shall be ascertained by the Bureau of Standards.

Reference Gage.—A commonly used name for a master gage. Sometimes such gages include those that represent the extreme limits of the product and are used to check the inspection and working gages.

Gages Used to Measure the Product.—The gages used to check the product may be divided into two general types: mechanical and optical. Both types, however, are controlled by the master gages. In general, most of the parts accepted by one method of gaging will be accepted by the other. It should be pointed out, however, that those parts which are close in size to either rejection-point, may be accepted by one system and rejected by the other.

Mechanical gages are often divided into two classes: inspection gages and working gages. Inspection gages are for the use of the inspector in accepting the product. They are generally of the same design as the working gages and the dimensions are such that they represent very nearly the extreme limits of the part being produced. Working gages are those used by the workman to check the parts as they are machined. It is recommended that, when successive inspections are required, the working gages, by either design or selection, be of such dimensions that they are inside the limits of the gages used in succeeding inspections.

When gages of the optical type are employed, the same or duplicate instruments are used for both classes of inspection. No distinction in size is necessary, as the elements of wear and "feel" are not involved in this method of measuring.

IV. Gaging Practices and Gages

The production of accurate parts is primarily a matter of eternal vigilance. The smaller the limits that are to be maintained, the more complete the inspection or gaging system must be. To secure satisfactory results, the manufacturing tools provided must be sufficently accurate and the manufacturing methods sufficiently reliable to produce the required results. After tools and methods of proved reliability are provided, the next point is to watch the wear on the tools or their set-up to assure the maintenance of the required conditions. This is accomplished sometimes by a periodical test of the tools, sometimes by periodical gaging of the product, and sometimes by both.

A screw-thread is comprised of several elements: first, the outside or major diameter; second, the pitch-diameter; third, the core or minor diameter; fourth, the angle of the thread form; and fifth, the lead. There is a broad general principle in regard to limit gages that should always be kept in mind. Where compound tolerances are not involved, a "Go" gage with fixed measuring surfaces may check as many dimensions at one time as desired, and effective inspection will be secured. On the other hand, an effective "Not Go" gage can check only one dimension. By effective inspection is meant assurance that specified requirements in regard to size are not exceeded.

The most difficult element of a screw-thread to gage is the lead. Lead-testing devices for checking tools and gages are available, but in general their operation is too slow for use as production inspection equipment. In addition, the lead is the most important element of a screw-thread as regards the nature of the contact between mating parts. Furthermore, an error in lead has almost double the effect of an equal error in diameter as regards interchangeability. Thus, for exacting threaded work, if the method of inspection of the parts produced does not effectively inspect for lead errors, the tools used to produce these parts must be carefully inspected for lead.

Thread Micrometers.—Thread micrometers are used extensively to measure the pitch-diameter of taps and threaded internal parts. Thread micrometers should be calibrated periodically against a master gage, to avoid errors due to wear on the anvils of the instrument. Thread micrometers give no indication of lead and angle errors; therefore, the results of tests with thread micrometers alone cannot be taken as conclusive.

Thread Snap-Gages.—Thread snap-gages, generally consisting of conical points, are commonly used to measure the pitch-diameter of screws and other threaded internal parts. As in the case of thread micrometers, these gages give no indication of lead and angle errors. Therefore, the results of tests with them alone cannot be taken as conclusive.

Ring Thread-Gages.—Ring thread-gages are used extensively to measure the thread on internal parts. These are usually adjustable and are adjusted to suitable master or reference gages. Where parts are to be produced within specified limits, "Go" and "Not Go" gages are required. The thread on the "Go" gage is made of full form with its major diameter cleared or undercut to give a suitable clearance for grinding or lapping. The "Not Go" gage should be made primarily to check the minimum pitch-diameter. The minor diameter of such a gage should therefore never be smaller than the minor diameter of its corresponding "Go" gage, and its major diameter should be cleared as in the case of the "Go" gage. The use of such gages gives a certain measure of lead and angle errors, as well as of pitch-diameter errors. A proper "Go" gage will reject any parts that exceed the maximum dimensions specified. The "Not Go" gage, however, does not necessarily reject all parts that exceed the specified cumulative tolerance. It is possible, with the use of such gages, to accept parts that exceed this cumulative tolerance because of lead or angle errors, or both. With the proper check on tools and manufacturing methods, however, such possibilities are the exception. Such gages have been used successfully for many years.

Thread Comparators.—A recent development in the art of measuring threaded parts is the thread comparator, usually an optical instrument. These optical instruments throw an enlarged image of the thread upon a screen where it is compared with the enlarged outline of the required form. The location of the form used for comparison is made to agree with the image of the master gage. With such instruments all errors, both individual and cumulative, of diameter, lead and angle can be determined readily. These instruments can be adapted to measure taps and threaded internal parts.

Plug Thread-Gages.—Plug thread-gages are used exclusively at the present time to measure threaded holes or threaded external parts. Where parts are to be produced within specified limits, "Go" and "Not Go" gages are required. The thread on the "Go" gage is made of full form with its minor diameter cleared or undercut to give a suitable clearance for grinding or lapping. The "Not Go" gage should be made primarily to check the maximum pitch-diameter. The major diameter of such a gage should therefore never be larger than the major diameter of its corresponding "Go" gage, and its minor diameter should be cleared as in the case of the "Go" gage. The use of such gages gives a certain measure of lead and angle errors, as well as of pitch-diameter errors. A proper "Go" gage will reject any parts that exceed the minimum dimensions specified. The "Not Go" gage, however, as in the case of the ring thread-gage, does not necessarily reject all parts that exceed the specified cumulative tolerance.

Methods of Inspecting Screws.—One practice of inspecting screws produced on automatic machines is to provide a ring thread-gage set to approximately the mean size between the maximum and minimum limits. The threading tools are then set so that the product enters this intermediate gage, but will not enter the minimum or "Not Go" gage. The machine is then started up and parts are tested periodically with the regular "Go" gage and the intermediate gage. When the parts have increased in size so that they will not enter the intermediate gage more than three or four turns, the set-up is changed, even though the parts are still acceptable to the "Go" gage.

A very similar plan can be followed when a screw-thread comparator is employed. The original set-up should be toward the minimum limit and the set-up should be changed as the maximum limit is approached.

Reference has been made to successive inspections. Although the manufacturer may give but one inspection, it should be realized that the purchaser often inspects the product to assure that the prescribed specifications have been fulfilled. Therefore, to reduce the possibilities of disagreement to a minimum, the manufacturer should strive to produce parts well within the specified limits rather than close to the limiting sizes.

Thread micrometers and thread snap-gages are used extensively for testing the product as it is produced. As these instruments do not test all elements of the screw-thread, a "Go" gage should always be used as a supplementary test. Thread micrometers are a very effective means of watching the change in set-up due to wear on tools, etc.

Methods of Inspecting Tapped Holes.—One practice of inspecting tapped holes is first to inspect the tap, and then test the tapped holes periodically with suitable gages. The tap can be watched for wear by testing the tapped holes with a "Go" thread-gage. One widely used practice consists of using a "Go" plug thread-gage and a "Not Go" plain plug-gage for the minor diameter.

Another practice of inspecting taps is to measure the several elements, such as pitch-diameter, angle and lead; and still another consists of tapping a hole with each tap before it is issued from the tool-crib and testing these tapped holes with "Go" and "Not Go" plug thread-gages.

V. Inspection of Gages

When successive inspections in the same plant are involved, it is good practice to inspect all gages of the same nominal size against each other periodically, and to distribute these gages so that the earlier inspections will be made with those that are the greatest amount inside of the component tolerance, and the later inspections with those gages closest in size to the component tolerance.

STORAGE-BATTERY DIVISION REPORT

Division Personnel

W. E. Holland, *Chairman*	Philadelphia Storage Battery Co.
I. M. Noble, *Vice-Chairman*	Consulting Engineer
G. L. Bixby	Detroit Electric Car Co.
R. N. Chamberlain	Gould Storage Battery Co.
E. L. Clark	Commercial Truck Co.
Bruce Ford	Electric Storage Battery Co.
W. E. Gossling	Prest-O-Lite Co., Inc.
C. T. Klug	Willard Storage Battery Co.
R. C. Mitchell	Edison Storage Battery Co.
J. L. Rupp	Westinghouse Union Battery Co.
G. W. Vinal	Bureau of Standards
W. G. Wall	National Motor Car & Vehicle Co.

Ratings of Storage Batteries for Isolated Electric-Lighting Plants

(Proposed S.A.E. Recommended Practice)

At a meeting of the Storage Battery Division in September the work in establishing a storage-battery rating for isolated electric-lighting plants was reviewed with particular reference to the action of the Isolated Electric-Lighting Plant Division on July 28, 1921, in recommending a standard rating of capacity expressed in terms of watt-hours based on a continuous 8-hr. discharge test. This recommendation did not receive general approval when submitted to letter ballot of storage-battery and lighting-plant manufacturers.

In view of the fact that at the present time several methods of rating storage-batteries are used, it is considered advisable by the Storage-Battery Division to recommend that either the intermittent or the continuous ratings should be used in accordance with the recommendation of the Storage-Battery Subdivision of the Electrical Equipment Division made on May 28, 1919. The present Storage-Battery Division is the successor of the Storage Battery Subdivision in existence at that time.

As the subject of storage-battery ratings was reassigned to the Storage Battery Division by the Council, the Storage Battery Division recommends for adoption as S.A.E. Recommended Practice the following methods of rating storage batteries for isolated electric-lighting plants.

RATINGS OF STORAGE BATTERIES FOR ISOLATED ELECTRIC-LIGHTING PLANTS

(1) Lead-acid storage batteries for isolated electric-lighting-plant service shall have two ratings, a continuous rating and an intermittent rating. The ratings shall be determined at an initial temperature of 80 deg. fahr. and be based on a final voltage of not less than 1.75 volts per cell.

(2) *Continuous Rating*—The continuous rating shall be the capacity in ampere-hours of the battery when it is discharged continuously at the 8-hr. rate.

(3) *Intermittent Rating*—The intermittent rating shall be the capacity in ampere-hours of the battery when it is discharged intermittently over a period of 72 hr.

In order to avoid night work, the following test is suggested:

> Discharge at a rate of current equal to 1/24 of the rated ampere-hour capacity of the battery for an initial discharge period of 4-hr., followed by a 16-hr. rest; then two 8-hr. discharge periods, each followed by a 16-hr. rest; the final discharge period being 4-hr.

The short periods at the beginning and at the end permit the test to begin at noon of the first day and end at noon of the fourth day.

(4) Except for the final voltage per cell the ratings apply to nickel-iron batteries as well as to lead-acid batteries.

(5) Battery manufacturers should specify both ratings in their catalogs using the following form:

S.A.E. Ampere-Hour Capacity Ratings: 100-140

The first number represents the capacity based on the continuous rating and the second number the capacity based on the intermittent rating.

As it is thought that the situation can be covered adequately at this time only by specifying both the continuous and the intermittent ratings, the Storage Battery Division makes this recommendation with the express understanding that in case either one of the two ratings proposed is eliminated by subsequent Standards Committee or Society action, the recommendation will be referred back to the Division.

Storage-Battery Monoblock Containers

(Proposed S.A.E. Recommended Practice)

In November, 1921 the standardization of storage-battery containers was suggested by a member of the Storage-Battery Division. A tentative proposal was submitted and considered at several meetings of the Storage-Battery Division during 1922, the proposal having met with the favorable consideration of storage-battery and hard-rubber manufacturers before final action was taken. Therefore

> The Storage Battery Division recommends for adoption as S.A.E. Recommended Practice the accompanying dimensions for storage-battery monoblock containers.

MONOBLOC CONTAINERS FOR STARTING AND LIGHTING BATTERIES

Height. — Containers shall be made in two heights only; namely, the B height for plates approximately 4¾ in. high, and the C height for plates approximately 5¼ in. high.

Overall Height.—The height from the outside of the bottom of the case to the top of the handle shall not exceed 9¼ in. for B containers, or 9⅞ in. for C containers.

Height from Top of Ribs to Top of Container.—These heights shall be:

B containers 6½ in. } Plus 0
C containers 7 in. } Minus 1/16 in.

Maximum variation between different compartments, 3/32 in.

Inside Width of Compartments.—5 31/32 in., plus or minus 1/32 in.

Inside Lengths of Compartments.—(a) 6-Compartment Containers

B Containers		C Containers	
S-3-B	1 5/16 in.	S-4-C	1 1/2 in.
S-4-B	1 1/2 in.	S-5-C	1 11/16 in.
S-5-B	1 11/16 in.		

(b) 3-Compartment Containers

B Containers		C Containers	
S- 7-B	2 1/16 in.	S- 8-C	2 3/8 in.
S- 8-B	2 3/8 in.	S-10-C	2 13/16 in.
S- 9-B	2 7/16 in.	S-13-C	3 1/4 in.
S-10-B	2 13/16 in.	S-14-C	3 5/16 in.
S-16-B	3 11/16 in.	S-16-C	3 11/16 in.
S-18-B	3 15/16 in.		
S-19-B	4 1/8 in.		

(c) Tolerances of plus 0 and minus 1/32 in. shall apply to container lengths of 3 5/16 in. or less and tolerances of plus 1/64 in. and minus 1/32 in. to lengths of over 3 5/16 in.

Partitions Between Compartments.—The thickness

of the partitions between compartments shall be 3/16 in. minimum and ¼ in. maximum.

Overall Width.—The overall width shall not exceed 7½ in.

It is the opinion of the Division that approval of the proposed recommended practice will result in its gradual adoption throughout the industry and effect a simplification of mold equipment. Although the monoblock container is relatively a new development, standardization will do much to prevent needless expense to the hard-rubber manufacturers in meeting unnecessary special demands of the automobile and the battery manufacturers.

It is not considered advisable by the Division to specify the outside dimensions for the containers as this would tend to limit development. It is thought, however, that the dimensions agreed upon will be a good basis for determining the ultimate outside dimensions.

TRANSMISSION DIVISION REPORT

Division Personnel

A. C. Bryan, *Chairman*	Durston Gear Corporation
L. C. Fuller, *Vice-Chairman*	Fuller & Sons Mfg. Co.
A. W. Copland	Detroit Gear & Machine Co.
A. M. Dean	Rubay Co.
D. E. Gamble	Borg & Beck Co.
A. A. Gloetzner	Covert Gear Co., Inc.
C. H. Grill	Foote Bros. Gear & Machine Co.
Joseph Jandesek	Formerly with Olds Motor Works
W. C. Lipe	Brown-Lipe Gear Co.
W. M. Petty	Service Motor Truck Co.
C. E. Swenson	Mechanics Machine Co.
E. E. Wemp	Long Mfg. Co.
S. O. White	Warner Gear Co.

Clutch Facings

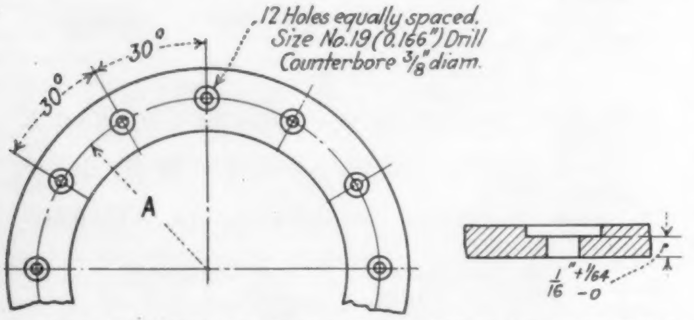
(Proposed S.A.E. Recommended Practice)

In March, 1922 the Society adopted the recommendation of the Transmission Division for clutch facings, the recommended practice now being printed on p. E19 of the S.A.E. Handbook. At a meeting of the Division held in October a report was submitted by A. C. Bryan covering the location of the rivet holes and the size of rivets, this having been submitted to manufacturers and users for comment. Although the Subdivision report at first recommended two concentric rivet-hole circles, it was revised to specify only one rivet-hole circle for each size of facing used for multiple discs, and the total number of circles for all facing sizes was reduced to three, thus necessitating but three sizes of drilling jig.

This action was considered to be in accordance with good clutch design as the members of the Division have experienced no trouble with fabric or molded types of clutch facing curling even with wider facings, when the rivets were placed in one rivet-hole circle. The maximum amount of wear was provided for by specifying that the thickness of facing from the bottom of the counterbore to the under side of the facing should be 1/16 in. with tolerances of plus 1/64 in. and minus zero, this being the minimum thickness to give the rivets sufficient hold. Therefore

> The Transmission Division recommends that the present S.A.E. Recommended Practice for clutch facings, p. E19 of the S.A.E. Handbook, be extended to specify the dimensions for locating the rivet holes and the rivet sizes for multiple-disc facings shown in the accompanying table.

The Division plans to give further consideration to the standardization of the rivet locations for single-plate clutch facings.



Proposed Dimensions for Clutch-Facing Rivets and Rivet Holes

Facing Size		A $\pm\frac{1}{32}$
Outside Diameter	Inside Diameter	
8½	6	$7\frac{3}{16}$
8½	6¼	$7\frac{7}{16}$
8½	6½	$7\frac{7}{16}$
8¼	6	$7\frac{3}{16}$
8¼	6¼	$7\frac{3}{16}$
8¼	6½	$7\frac{7}{16}$
8	5¾	$6\frac{15}{16}$
8	6	$6\frac{15}{16}$
8	6¼	$7\frac{3}{16}$

TRUCK DIVISION REPORT

Division Personnel

F. A. Whitten, *Chairman*	General Motors Truck Co.
A. J. Scaife, *Vice-Chairman*	White Motor Co.
A. K. Brumbaugh	Autocar Co.
G. S. Cawthorne	Master Trucks, Inc.
J. R. Coleman	Selden Truck Corporation
F. W. Davis	Consulting Engineer
H. E. Derr	International Harvester Co.
A. W. Herrington	War Department
M. C. Horine	International Motor Co.
H. B. Knap	Packard Motor Car Co.
W. M. Petty	Service Motor Truck Co.
C. B. Veal	Manly & Veal

Vertical Dumping-Hoist Platforms

(Proposed S.A.E. Recommended Practice)

The standardization of vertical dumping-hoist platform mountings was discussed at a recent meeting of the Truck Division, but it was felt that not much can be done in this connection except to indicate in a general way what is considered good practice as to the method of fastening the hoist platform to the truck frame. Therefore

> The Truck Division recommends for adoption as S.A.E. Recommended Practice that in mounting vertical dump-hoist platforms no holes shall be drilled through the frame flanges or in the web near the flanges, but that where the frames are drilled the holes shall be on or near the neutral axis of the frame section.

Three-Joint Propeller-Shafts

(Proposed Revision of S.A.E. Recommended Practice)

The present S.A.E. Recommended Practice for Three-Joint Propeller-Shafts, p. E6a of the S.A.E. Handbook, was criticized at the time of its adoption in March, 1922 by several of the Society members to the effect that the square type of shaft-end should not be included in the standard as it is not widely used. This matter was considered at a recent meeting of the Truck Division and, although it was felt that the square shaft-end is not the

best construction for three-joint propeller-shafts, it was decided not to revise the recommended practice unless a general inquiry should substantiate the criticism. A letter was therefore sent out and, as the replies indicated that this type of shaft-end is not used extensively,

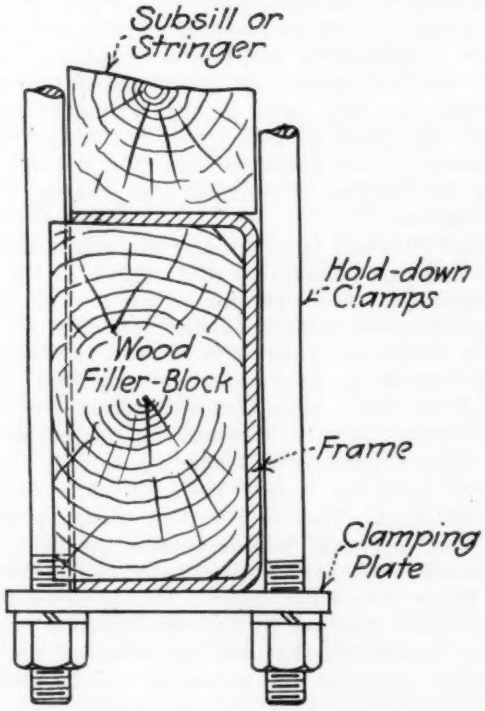
The Truck Division recommends that the present S.A.E. Recommended Practice for Three-Joint Propeller Shafts, p. E6a of the S.A.E. HANDBOOK, be revised by eliminating the square type of shaft-end.

BODY HOLD-DOWN CLAMPS

(Proposed S.A.E. Recommended Practice)

Discussion of body hold-down clamps at the Truck Division meeting in July indicated that standardization of a general type of clamp would lead to improved practice in many instances. Although this subject will probably be of more interest to body builders than to truck builders inasmuch as the former usually make their own clamps, it is felt that a recommendation should be adopted as a guide to the more general use of an effective, inexpensive method of fastening truck bodies to frames. Therefore

The Truck Division recommends for adoption as S.A.E. Recommended Practice that neither the top nor the bottom flange of motor-truck frames shall be drilled for body or hoist platform hold-down clamps, but that U-clamps shall be used with a wood block filler between the frame flanges to prevent bending, in a manner similar to the construction shown in the accompanying illustration; and that the use of too many hold-down clamps for securing the body to the frame be guarded against, particularly in mounting a very stiff body such as those used for oil-tanks.



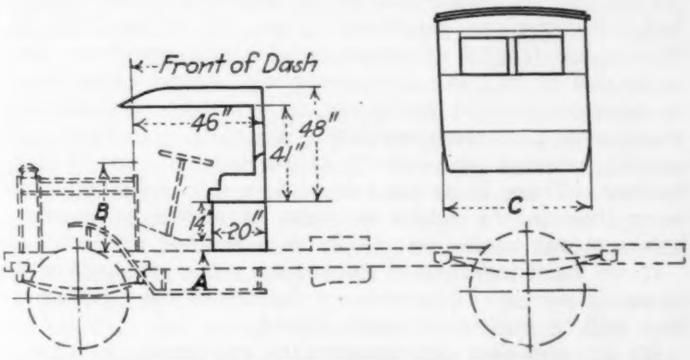
MOTOR-TRUCK CABS

(Proposed S.A.E. Recommended Practice)

Early last spring it was decided to undertake the standardization of motor-truck cab mounting-dimensions to save the loss of time and expense in fitting cabs to truck chassis and to make it possible for truck operators to change a cab from one chassis to another when desired. Information was obtained from truck builders as to the mounting dimensions required for cabs used on their trucks; this was tabulated and analyzed, and a tentative recommendation was based on it. The recommendation was reviewed, together with comments received from motor-truck cab builders, and was modified.

The revised recommendation was referred to motor-truck and cab manufacturers for final comment, the comments received being referred to the members of the Truck Division and final Division action taken by letter ballot. Therefore

The Truck Division recommends for adoption as S.A.E. Recommended Practice the motor-truck cab dimensions given in the accompanying table.



PROPOSED MOTOR-TRUCK CAB DIMENSIONS

Truck Capacity, Tons	A	B[6]	C
1, 1½, 2, 2½	3½	35	48
3, 3½, 4, 5	4	39	56

[6] Minimum for windshield lower edge. Where cab sides, doors or side curtains are used, care should be taken that the driver's vision shall be interfered with as little as possible.

It is not expected that the cab dimensions proposed will permit the installation of stock cabs on all chassis now built. The modus operandi has been to strike an average of the prevailing practice with due regard to the possibility of tempering such practice to meet that of the largest number of users. The recommendation will offer the opportunity.

Detroit Production Dinner

AT the Production Dinner in Detroit in October, which was not only an unusually intimate occasion but also a liberal education on the necessities and possibilities of cooperative methods in production, H. H. Emmons, who was in charge of Liberty-engine production during the war, Past-President Kettering and P. S. du Pont, president of the General Motors Corporation, gave inspiring talks. These are reproduced in large part herewith. A. B. C. Hardy, president and general manager of the Olds Motor Works, was the principal speaker of the evening. His address is printed elsewhere in this issue of THE JOURNAL.

P. S. DU PONT

I AM struck frequently, as we go on with our daily problems in the automobile industry, how discouraged we are over many things that in the future will seem very light. It is because we do not understand our problems; we are fearful, because we do not understand, that somebody else may and get ahead of us. We in the General Motors are fearful of somebody else and somebody else is fearful of us. We are struggling against each other in imagination, but really not in practice. We are all working on a common problem. What one man finds out quickly becomes the property of everyone to expand still further. There is nothing fearful in this industry, any more than in the simple problem of smokeless powder before it was turned out finally as a finished product.

If we work together in the industry the problems will be easily solved. If we are not fearful of the problems, they will be still more easily solved.

We all know that our present cars, our present engines, everything, are very imperfect. I believe all of you could tell me, as I cannot tell you, just how imperfect our operations are. That makes the problem all the more interesting. We are fortunate to be in this industry which is an infant. There is before us now, not only the world of our own industry, with its many ramifications and possibilities of development, but there are thousands of uses of the automobile that we do not picture to-day. We have only scratched the field. This is the only country in the world that uses the automobile, as you know, and yet the bulk of the population is elsewhere with its own problems, peculiar problems, if you will, but all before you to be solved. All of us have a wonderful opportunity because we will all have some years in this industry and the next few years are going to be full of developments of interest for us.

I congratulate the Society on mustering so many men together, and so many brains, on these problems. I wish you all happiness in the development of them and I only hope I may share to a certain extent in your troubles and in your successes.

H. H. EMMONS

I AM very glad to have the privilege of being here to-night and seeing so many of the men with whom I was associated during the 2 years that I look back on with the most pleasure of any in my existence, because the production of aviation engines during the war, under the conditions in which it was started and in the way in which it had to be handled and the tremendous results that were achieved, constitutes, I think, the most remarkable production program that was ever put through in the history of industry. That was due to the men in the factories, the engineers and the production men.

It is a real pleasure to think of the time when that wonderful job was accomplished, when the Liberty engine was struck from the minds of two or three men in the course of 2 or 3 days and was put into production by one of the factories here in Detroit whose production man sits at this table, within 4 months after it had passed its tests, the production reaching within 13 months 15,570 engines complete with spare parts equal to 55 per cent in addition. There were working on the program for the making of 100,993 aviation engines, over 200,000 men and women in the factories and parts plants, an enthusiastic, whole-hearted crew of people, who had but one thought, to get out the most engines, of the best quality, in the shortest possible time. The result was that before the armistice was declared, of all seven types of aviation engine made in this Country, over 33,000 were delivered into service complete with their spare parts, between May, 1917, and November, 1918.

The Liberty aviation engine has never been surpassed for all-round efficiency by any other engine of similar type. It is used to-day by all the services of the Government engaged in aviation activities. The Post Office Department uses it almost exclusively. Some of the races that were held in Detroit recently were won by airplanes that were propelled by the Liberty engine. Other engines of excellent design and workmanship were made here during the war, such as the Hispano-Suiza. The work that was done at that time by the engineers and the production men stands to-day for the benefit and service of the Nation; it is one of the greatest assets the Air Service has.

The main function of every one connected with industry is to help the production man, assist in the production of material. A lawyer may draw a wonderful contract or an engineer make a wonderful design, but neither of them is worth the paper it is written on if it does not help some fellow to produce something that somebody wants and can use. Now that the automotive industry has passed from infancy to manhood, the proposition of engineering and production comes again into the public eye, in the birth of a new baby, namely, commercial aviation material. That is the next thing before us to handle. That material will be needed as badly and as quickly as the other automotive material has been heretofore. Those who have studied the question of aerial navigation with relation to national defense know that it is most important that we get aviation on a basis where civilian airships and airplanes will be constructed so that they will furnish the absolutely essential and fundamental element of national defense, as to both material and personnel. There is no place where engineering and production should be combined so promptly and with such effect as in the development and production of this material.

The time of fighting wars in the old style has gone. A war between two adjoining nations will be decided in a few hours. There will be no time to mobilize a body of troops or handle a fleet of battleships. The nation that will defend itself must have control of its own air. We have an enormous boundary-line, both land and water. To provide in the naval or military service a defense in

the air would cost us an enormous amount of money. If we develop civil aerial navigation with equipment that can be converted for use in war, and have the aviators trained and regulated so that they will be able to handle the dropping of bombs as well as the transportation of passengers and express, we shall have very cheaply and very efficiently the national defense we need. To that end, I hope that the engineer and the production man will take to heart all of the lessons that have been learned in automotive industry.

C. F. KETTERING

WHEN we engineers design a thing, and the production man starts to make it and puts it together, it is never what we designed. Then we have to go back and do the job all over again. There is a certain amount of relief in that, because nobody is responsible for the production then. There has been a good bit of reason for that. Things have had to be produced in a certain length of time, and engineers have proposed certain types of material that could not be obtained. Since we have had modern metallurgy, when a part is not strong enough, all we have to do is get another type of alloy-steel. That serves until the customer gets it. I was in a shop not long ago where they had 57 different kinds of alloy-steel to cure the same trouble. By the time it was cured the article was out of production.

The time for the production engineer to sit in is before the thing is designed. I believe that this industry has spent hundreds of millions of dollars, foolishly, by not calling the production man in when the design was in process. We do many things in engineering work that inflict on the factory problems that have had no thought at all.

Your designing engineer will work up the machine. You may build a model. A thing may function properly. The drawings will be prepared for production. A number of the little details in those production drawings are put in without any brains at all. A draftsman you hired day before yesterday will put in fillets and impossible sets of conditions that the production man cannot carry out. Those drawings will go to your tool-design department and your tool-makers will try to make the tools from the design. You will attempt to manufacture the parts, with the net result that the whole thing is made exceedingly difficult to do, many times, when neither the designing engineer nor the production manager has had a chance to touch the real cause of the trouble.

I believe that we do not need to be overly secret after we get a design worked out so far as the production engineering is concerned. I think that the production men should have a chance to look at the design before it is finally crystallized. No designing engineer should be fastidious about changing a drawing to facilitate production.

We have found that turning wooden models of the pieces under question over to the factory men to look at has paid for the cost of the models more than a hundredfold. Making up a casting in such a way has resulted in suggestions from the pattern-shop and the foundry that have simplified the design, the methods of location and what not, saving thousands of dollars in tooling.

There should be no dissension among production and engineering men. The two closest fellows in any organization should be the production man and the engineer. A third man who has never been there should come into the picture, the accounting man. Cost accounting as we know it to-day is historical; sometimes very historical. Our designing engineers and our production engineers will not get to the real finality of this thing until the question of costs is considered in connection with every line of the design. I do not mean that a design should necessarily be cheap, but that it is the worst type of economy to spend a dollar in the production of any piece that does not render a dollar's service to the customer. If the cost accountant injects fundamental economies into the job when it is being designed, the designer, the production man and he can work out a product that will be better, serve the customer better and make the final amount in the bank greater.

It seems to me that this Production Meeting marks an epoch in the history of the automobile engineer. We should consider more and more the question of the productability of a piece and its cost, before completing designs. Once we do that, we shall proceed into the finality of the job, just as the Society has tried to carry out the standardization of materials.

In the case of any design we should not think of it first in terms of a special machine. A special machine should be considered only after a standard machine has been thoroughly considered. The question of design should carry with it a picture of the floor space, the capital investment and all the other things that enter into the ultimate cost of the article. We have been interested too much in labor and material; and overhead has been a plaster that we put on regardless, without bearing in mind that it is just as great a factor as, and sometimes many times greater than, the labor, and occasionally equal to the labor and the material. We do not always recognize that when we design a piece of apparatus we are automatically laying-out shops, including all the things that are involved in the fabrication.

So, in this twenty-first year of our industry, it seems to me that we should appreciate that the ultimate cost of an article is its cost when it is on the shipping platform and that this cost can never be reduced to its lowest possible minimum until all of the factors that enter into the cost sheet shall have been taken into consideration.

I am certainly glad to have had the opportunity to be at this meeting and see the production men and the engineers together. We have been a loyal bunch of scrappers. Each side has thought the other has been somewhat off color and perhaps both were right. If we get together in all of our work we shall produce a better article for our customers.

We ought to make automobiles that can be repaired when and as they break. We should be able to repair them with some of the tools that are in the tool-kit. The thickness of the instruction-book should be greatly reduced. To-day, the kit of tools and the instruction book are the great engineering alibis of the automotive industry.

It does not cost much to mark on the tool the use to which it is to be put. Many of you have never bought a new automobile. Maybe you have driven some you have designed. If you should buy a car, have something happen to it, and take out and look at the tool-kit, what you would finally do is to take the pliers and fix the trouble.

For a small price you can indicate with a stamp what those tools are to be used for. All such things are a part of engineering. All of them will help to make our boss, the customer, happy and willingly subscribe a certain amount to the payroll. If we will recognize that the future of our industry depends upon how well and

how easily we can put into the hands of the customer the automatic transportation he never had before, we will have solved the great problem of the automotive engineer.

It is not making so many machines. It is not melting up so many tons of cast iron. It is not making so many wonderful designs, putting on various types of things. That is not the question. We must do something else. To-day, we have bumpers on the front and the rear of the car. We have cozy wings, cigar lighters. We have every conceivable thing that you can think of on cars. We cannot get anything more on unless we increase the wheelbase.

The big question is whether that provides economical and desirable transportation. In the degree that you render that desirable transportation by furnishing a minimum amount of material, and a minimum number of places for the car to get out of order, just so far will you have gone in fulfilling the mission for which the Lord has apparently created you.

S.A.E. STANDARD BABBITT SPECIFICATIONS

A SERIOUS error in the publication of the S.A.E. Standard specifications for babbitt, or white bearing metals, in the August 1922 issue of the data sheets has been brought to the attention of the Society. Specifications Nos. 11, 12, 13 and 14 do not cover the maximum amounts of the various impurities that were given in the original babbitt specifications of which they were revisions. It was not the intent of the Non-Ferrous Metals Division to omit specifying the impurities but, as the report of the Division as acted upon at the Standards Committee Meeting in June did not refer to allowable impurities in the specifications, the report was so printed in the S.A.E. HANDBOOK, pp. D103 and D104.

In order that the members of the Society may note in their Handbooks the additional elements covered by these specifications, the complete babbitt specifications are reprinted below, the matter omitted in the August 1922 issue of data sheets being printed in italics.

WHITE BEARING METALS

The limits for the chemical compositions specified for metal in ingot form are closer than the limits specified for cast products, as allowances have been made for variations in the chemical content due to casting.

SPECIFICATION NO. 13, BABBITT

Composition in percentage.

	Cast Products	Ingots
Tin	4.50 to 5.50	4.75 to 5.25
Antimony	9.25 to 10.75	9.75 to 10.25
Lead, max.	86.00	85.50
Copper, max.	0.50	0.50
Arsenic, max.	*0.20*	*0.20*
Zinc and Aluminum	*None*	*None*

General Information.—This is a cheap babbitt and serves successfully where the bearings are large and the service light. It should not be used as a substitute for a babbitt with a high tin-content. It is also suitable for die-castings.

SPECIFICATION NO. 14, BABBITT

Composition in percentage.

	Cast Products	Ingots
Tin	9.25 to 10.75	9.75 to 10.25
Antimony	14.00 to 16.00	14.75 to 15.25
Lead, max.	76.00	75.25
Copper	*0.50*	*0.50*
Arsenic, max.	*0.20*	*0.20*
Zinc and Aluminum	*None*	*None*

General Information.—This is a cheap babbitt and serves successfully where the bearings are large and the service light. It should not be used as a substitute for a babbitt with a high tin-content. It is also suitable for die-castings.

SPECIFICATION NO. 10, BABBITT

Composition in percentage:

	Cast Products	Ingots
Tin, min.	90	90.75
Copper	4 to 5	4.25 to 4.75
Antimony	4 to 5	4.25 to 4.75
Lead, max.	0.35	0.35
Iron, max.	0.08	0.08
Arsenic, max.	0.10	0.10
Bismuth, max.	0.08	0.08
Zinc and Aluminum	None	None

When finished bronze-backed bearings are purchased a maximum of 0.6 per cent lead is permissible in scraped samples provided a lead-tin solder has been used in bonding the bronze and the babbitt.

General Information.—This babbitt is very fluid and may be used for bronze-backed bearings, particularly for thin linings such as are used in aircraft engines. It is also suitable for die-castings.

SPECIFICATION NO. 11, BABBITT

Composition in percentage:

	Cast Products	Ingots
Tin, min.	86.00	87.25
Copper	5.00 to 6.50	5.50 to 6.00
Antimony	6.00 to 7.50	6.50 to 7.00
Lead, max.	*0.35*	*0.35*
Iron, max.	*0.08*	*0.08*
Arsenic, max.	*0.10*	*0.10*
Bismuth, max.	*0.08*	*0.08*
Zinc and Aluminum	*None*	*None*

General Information.—This is a rather hard babbitt which may be used for lining connecting-rod and shaft bearings which are subjected to heavy pressures; its "wiping" tendency is very slight. It is also suitable for die-castings.

SPECIFICATION NO. 12, BABBITT

Composition in percentage:

	Cast Products	Ingots
Antimony	9.50 to 11.50	10.25 to 10.75
Copper	2.25 to 3.75	2.75 to 3.25
Lead, max.	26.00	25.25
Tin, min.	59.50	60.00
Iron, max.	*0.08*	*0.08*
Bismuth, max.	*0.08*	*0.08*
Zinc and Aluminum	*None*	*None*

General Information.—This is a relatively cheap babbitt and is intended for bearings subjected to moderate pressures. It is also suitable for die-castings.

Coming Meetings of the Society

THE ANNUAL MEETING

THE Annual Meeting of the Society will be held in New York City, Jan. 9 to 12. These dates occur during the week of the National Automobile Show and the Automobile Body Show, thus enabling the members to visit these important exhibitions while in the city for the Society meeting. The valuable knowledge that can be gained from the two shows and the representative group of papers at the Society meetings will amply repay each member for the time and expense of attendance. The following paragraphs announce such details of the program and arrangements as are definite at this time. Lay your plans to be in New York City from Jan. 9 to 12.

Reduced Railroad Fares

Negotiations are under way with the Trunk Line Association to secure reduced railroad fare concessions for the benefit of members who attend the Annual Meeting. Members will be required to secure special certificates from the local railroad agent when purchasing tickets to New York City. These certificates must be presented for validation at the Transportation Desk at the Annual Meeting. *Absolutely no certificates will be validated for any person not a member of the Society.* The Society is held accountable under the Interstate Commerce laws for any violation of the agreement limiting the reduced-fare privilege to members and dependent members of their families. Regardless of any assurance given by local railroad officials, there will be no certificates validated at New York City unless they are presented by persons whose membership is evidenced by our records. Complete details of the reduced-fare plan will reach the members in an early issue of the *Meetings Bulletin*.

The Annual Dinner

The Annual Dinner will be held at the Hotel Pennsylvania Thursday evening, Jan. 11. The Dinner is one of the established features of Show Week and is nationally regarded as the outstanding gathering of representative automotive men held during the year. Our genial friend, C. F. Kettering, will serve us again as toastmaster. There will be one formal after-dinner address and past experience has demonstrated that the speaker will be selected because his message is of direct interest to the men in the industry. Tickets for the Dinner should be ordered at once using the form printed at the bottom of this page. Preference as to location of tables will be accorded applications in the order of their receipt.

It has been decided by the Council and Meetings Committee to eliminate the Carnival of past years from the 1923 program. This is largely due to the fact that, when staged with the proper degree of decoration, novelty and splendor this event can not be made self-supporting financially unless prohibitive rates are charged for admission.

The Technical Sessions

All technical meetings will be held in the Engineering Societies Building at 29 West 39th Street. The morning meetings will start promptly at 9:30, one-half hour earlier than in previous years. The afternoon meetings will start at 2 o'clock and the evening meetings at 8 o'clock.

The Annual Standards Committee Meeting, Tuesday morning and afternoon, Jan. 9, will include many important reports upon which action as to adoption, revision or rejection will be taken. The reports to be considered will be found in this issue of The Journal and should be studied by the members so that pertinent suggestions or criticisms may be presented at the meeting.

Body Engineering

It is probable that two Body Engineering Sessions will be held at the Annual Meeting, on Tuesday and Wednesday afternoons, respectively. L. V. Pulsifer will present a very comprehensive paper on the testing of automobile paints and varnishes including actual demonstrations with laboratory apparatus. George J. Mercer will read a paper on the design and construction of less expensive closed bodies. The standardization of lumber sizes and specifications will be the

S. A. E. ANNUAL DINNER

APPLICATION FOR TICKETS

Society of Automotive Engineers, Inc.
29 West 39th St., New York City. Order of Receipt ————

Gentlemen:—

Please mail me tickets for the Annual Dinner at the Hotel Pennsylvania, New York City, Jan. 11, as follows:

.... tickets for members at \$6.00.
.... tickets for non-members at \$7.00. } **I enclose check for \$........ and list of guests.**

I understand that all dinner seats are reserved; that preference as to location will be accorded applications in the order of their receipt; and that each table seats ten.

I also understand that dinner tickets are not subject to cancellation or refund after Tuesday, Jan. 9.

Signed ....

Please enclose list of those for whom these tickets are intended.

Address ....

....

topic of a paper by F. F. Murray. Other papers are under consideration and will be announced later.

AERONAUTIC SESSION

The plan for the Aeronautic Session, Tuesday evening, Jan. 9, is rather unique. Five or six outstanding authorities on commercial aircraft are being invited to present brief opinions on certain fundamental design problems whose solution is considered necessary before commercial aviation can progress. These opinions will be thoroughly discussed and debated with the hope that the resultant interchange of thought may clarify the present dilemma as to what constitutes a truly practicable and profitable commercial airplane. Names of the contributors to this symposium will be announced later.

The meeting on Wednesday morning, Jan. 10, will include the annual reports of the Treasurer and of the Sections, Meetings and Membership committees. Ballots for the election of officers for 1923 will be counted and the result announced. President Bachman will present his annual presidential address at this session.

FUEL AND ENGINE PAPERS

Prof. G. A. Young will present a paper on Practical Methods of Securing High Compression Without Detonation at a technical session to be held Wednesday afternoon, Jan. 10. This paper brings out some interesting results of research work conducted in the laboratories of Purdue University. This will be followed by a paper by Thomas Midgley, Jr., outlining the Fundamental Laws Governing Detonation. A third paper on a Means of Measuring Detonation and Comparing Fuels for Use in High-Compression Engines will be presented by Stanwood W. Sparrow and S. M. Lee, of the Bureau of Standards research staff. It will be noted that this group of three papers is concentrated on the detonation phase of the automotive fuel problem.

Robert E. Wilson will present the first paper at another meeting devoted to fuels on Thursday afternoon, Jan. 11. His paper will discuss the Function of Oil and Fuel in Crankcase Dilution. C. S. Kegerreis will read a paper on the Carburetion of Gasoline and Kerosene. It will outline metering characteristics and the temperatures necessary for good performance; data on air and fuel flow will be supplied and specifications for an ideal carbureter presented.

COOPERATIVE FUEL RESEARCH SESSION

One entire session on Thursday morning, Jan. 11, will be devoted to reports and discussion of the progress made in the Cooperative Fuel Research project that was formulated by the Research Department of the Society. The expense of this fuel-volatility research has been borne jointly by the National Automobile Chamber of Commerce and the American Petroleum Institute representing the automobile and petroleum industries, respectively. The research work has been done largely at the Bureau of Standards in the city of Washington although many other agencies have been cooperating in the tests. Dr. H. C. Dickinson, manager of the Society's Research Department, W. S. James and R. E. Carlson, of the Bureau of Standards, and H. M. Crane, chairman of the Research Committee, will address this meeting. The discussion of the conclusions reached as a result of the tests is expected to be most valuable and complete.

AIR-COOLED ENGINES

Two simultaneous sessions are scheduled for Friday morning, Jan. 12, with two papers in each. A very complete paper on Air-Cooling of Passenger Car Engines will be presented by S. D. Heron of the McCook Field engineering staff. Mr. Heron has had very broad experience in the development of satisfactory air-cooled airplane engines both in England and this Country. He will set forth certain design recommendations from his experience that are applicable to passenger-car engine design. The paper will carry appendices by C. F. Taylor on the testing of air-cooled engines and by E. H. Dix, Jr., on the foundry and metallurgical problems of the air-cooled cylinder. Prof. E. H. Lockwood will read the other paper in this session and will present data and empirical formulas on the Cooling Capacity of Automobile Radiators. Thus the two opposing methods of engine cooling will be touched upon in this session.

Herbert Chase has written a comprehensive paper on Steering and Steering Gears that follows in plan his commendable paper on Clutches. He will include a very complete analysis of the conditions responsible for front wheel wobble.

A paper on the lubrication of pistons and cylinder walls, by A. Ludlow Clayden, will also be presented at this session.

It should be apparent to any one studying this program of valuable papers that attendance at the forthcoming Annual Meeting will result in material benefit to him. The technical sessions may be likened to post-graduate lectures on automotive engineering designed to keep the engineers in the industry informed of the very latest scientific advances in the art. The standard of papers maintained at the Society's national meetings has resulted in the raising of its programs to the highest plane. Engineering authorities, research laboratories, educators and scientific men look upon these meetings as logical forums for the presentation of their research data. The supply of papers was so great this year that it became necessary to close the Annual Meeting program in September. This reflects a very healthy condition so far as the continuing success of the technical activities of the Society is concerned.

Arrange NOW to be in New York City, Jan. 9 to 12!

THE CHICAGO SERVICE MEETING

THE Chicago Meeting of the Society will be held during Chicago Show Week on Wednesday, Jan. 31. Morning and afternoon technical sessions are being arranged by a local committee headed by B. S. Pfeiffer. The papers and discussion will be confined to vehicle operation and maintenance, particular attention being given to the work of the service-station. The speakers selected will be men either operating large service-stations or responsible for the maintenance of large fleets of vehicles. The program of papers will be announced in the January issue of THE JOURNAL.

The Chicago Dinner will be held on the same evening. Here again, automotive service will be the major topic. The arrangement of the Dinner program is vested in a Chicago Committee of which Taliaferro Milton is chairman. Definite plans will be announced later.

It is anticipated that reduced railroad-fare concessions can be secured from points in the automotive territory for the benefit of members attending the Chicago Meeting. Watch for definite announcement regarding this in an early issue of the *Meetings Bulletin*.

COMING SECTIONS MEETINGS

Will Be Found Described in This Issue of THE JOURNAL on p. 564

Research Topics and Suggestions

THE Research Department plans to present under this heading each month a topic that is pertinent to the general field of automotive research, and is either of special interest to some group of the Society membership or related to some particularly urgent problem of the industry. Since the object of the department is to act as a clearing-house for research information, we shall be pleased to receive the comments of members regarding the topics so presented, and their suggestions as to what might be of interest in this connection.

SPRINGING AND COMFORT

MUCH has been written of late, both here and abroad, on the subject of springing and riding qualities, but most of the literature passes over one phase of the subject that is certainly of major importance, namely, the physiological effects produced by the action of the vehicle upon the average person. The subject has received some general consideration, to be sure. As early as 1907, F. W. Lanchester made a statement, which may be found in the *Proceedings of the Institution of Automobile Engineers*,[1] to the effect that a period of vibration longer than 90 to 100 oscillations per min. is comfortable, while a shorter period is uncomfortable; he does not state, however, what is the basis for this conclusion. Comfort in railroad travel is discussed in a paper by Georges Marie in the *Revue Generale des Chemins de Fer*[2]; the author of this article, however, deals with the comfort of invalids rather than that of normal passengers. In the *Proceedings of the Institution of Automobile Engineers*,[3] there is a discussion by a number of engineers as to whether it is the acceleration or the rate of change of the acceleration that is felt by the passenger. Nowhere in the literature do we find an attempt to make an analysis of the relation between vehicle performance and riding comfort. There are certainly various features of performance that affect the average person favorably or unfavorably. Probably not all people are sensitive to the same characteristics, or in the same degree. The fact remains, however, that the so-called riding qualities of different cars are remarkably different, and that the degree of fatigue experienced on long trips is very different for different vehicles.

If spring-suspensions and vehicle design in general are to continue to improve as regards comfort, it is important to know definitely what constitutes comfort, and this should be known as regards the average person. We shall confine this discussion entirely to the mechanical treatment that the passenger receives from the vehicle, omitting such questions as quietness, visibility and temperature, as well as driving qualities as distinct from riding qualities.

Most engineering problems are extremely complex, presenting many variable factors. Experimental attack on any problem, however, requires that it be expressed in reasonably simple terms and that the variables be reduced to a very few. The problem in hand is no exception. The possible motions of a vehicle are infinite in amplitude, period and direction. Yet, to be susceptible of experimental study, they must be classified and expressed in reasonably simple terms. We believe this can be accomplished to some extent and some suggestions along this line are given in the following paragraphs. Moreover, the experimenter almost always works on some hypothesis, which, however, he must always remember is only a hypothesis until proved a fact. We shall venture to suggest a few hypotheses.

If a vehicle were traveling at a uniform speed in a straight line, the occupants would be entirely unaffected by the motion; only movements of the vehicle that are departures from uniform straight-line motion produce reactions that can affect him. We may therefore neglect the uniform forward velocity and consider only such motions as are superposed on this. Considered in this way, the chassis and body have six degrees of freedom; they can have translations in each of three directions and can rotate about three axes, within the limits of motion imposed by the springs, the road, and other limiting factors. The only three axes of translation and rotation that can be chosen logically in this instance are the longitudinal axis of the vehicle; a transverse axis at right angles to it, and a vertical axis.

Bearing in mind that uniform motion in a straight line does not have any reaction on the passengers, and therefore considering only those motions of the vehicle that are a departure from this condition, the possible motions are somewhat as follows:

(1) Motions of translation in the direction of the axis, the result of acceleration or deceleration from engine power, brakes or road grades or shocks
(2) Vertical motions due to road-surface irregularities and grades, to which attention is usually confined in considering spring action
(3) Transverse motions mainly due to curves in the line of travel
(4) Rotary motions about the longitudinal axis of the vehicle, due to inequalities in the road from side to side, or to irregular engine-torque
(5) Rotary motions about a transverse axis, or "pitching" due to road-surface irregularities
(6) Rotation about a vertical axis that occurs in driving around curves

So much for the *direction* of transverse and rotary motions. As for the character of these motions, they may be of almost infinite variety, from the gradual acceleration on speeding-up smoothly from a low to a high speed, to the intense shock produced by striking an obstruction in the road, but they have one feature in common; they are all felt by the passenger as *pressures* applied at some part of his body. These pressures are proportional to the accelerations that are imparted to the passenger, but it is probable that the duration of these pressures or the rate at which they change has as much to do with the sensations produced as does the magnitude of the pressures. The duration is certainly of importance because, if the pressure be applied for a very short time as, for example, when the displacement is very small, as when striking a small road irregularity, the passenger is subjected to only a sort of surface effect, while, if the displacement be greater or the pressure applied for a longer time, as when passing over a considerable bump in the road, the motion is felt internally as well as externally.

In the normal operation of vehicles, the kinds of motion that occur in the different degrees of freedom are decidedly different.

(1) Horizontal motions in the direction of driving are of two distinct kinds
  (*a*) Accelerations or decelerations due to engine power or brakes. These motions are of relatively long period and of moderate intensity. The average car has on direct drive an acceleration under one-tenth that of gravity; hence the occupant is seldom subjected to a horizontal force much exceeding one-tenth of his weight in acceleration. In braking, the force in the other direction may be considerably greater, but such violent use

[1] See *Proceedings of the Institution of Automobile Engineers* (1907-8), p. 132.

[2] See *Revue Generale des Chemins de Fer*, May, 1907, p. 249, and June, 1907, p. 367.

[3] See *Proceedings of the Institution of Automobile Engineers*, vol. 7, p. 75.

of the brakes is hardly a common occurrence, or should not be

(*b*) The other class of motions are those due to inequalities of road surface and resulting component of impact in a horizontal direction, since the effect of striking a small obstruction is to produce only a small change in a relatively high velocity and, since the effect is also combined with a marked vertical motion, the effect of the horizontal component of these forces often has been overlooked. A paper by H. M. Crane, entitled A New System of Spring-Suspension for Automotive Vehicles,[4] discusses this point. If tests were made with a vehicle at rest on a moving bumpy road, doubtless this effect would be more generally recognized. Most spring-suspensions have no cushioning effect whatever in the horizontal direction; it is left to the tires to absorb such shocks. The forces transmitted to the occupants of the car in a horizontal direction would probably be found to be unexpectedly large if adequate measurement of them were made. A few measurements have been made

(2) Vertical displacements are, of course, generally considered the most important. It is these that are considered almost exclusively in spring design. So much has been said and written on this subject that it is necessary here only to call attention to the fact that one class of motions that is usually not included in the discussion of spring action may have an unexpected importance, namely, the very-short-period vibrations of parts of the chassis due to shocks of various kinds. It is said that acceleration as high as four times that of gravity has been measured under conditions where the spring deflection could not account for half this acceleration. Such motions must be of exceedingly small amplitude, but they may have great physiological importance

(3) In a properly designed vehicle transverse forces probably are confined almost entirely to centrifugal action due to curvature of the line of motion, since there are no important transverse forces other than those due to centrifugal force. These forces are relatively small and infrequent in ordinary driving, and we doubt whether their effect on the occupants of the average vehicle is of much importance

(4) The effects of rotary motion about the longitudinal axis of the vehicle are recognized as unpleasant, whether they be due to "rolling" of the chassis or to irregular engine-torque. The former are more or less periodic, with a relatively slow period, and the latter are of such short period as to have, probably, about the same effect as vibrations of very short period and small amplitude in any other direction

(5) The pitching motions of a vehicle, or rotations about a transverse axis, seem to be in a class by themselves. Their period is much more nearly uniform than that of any other type of motion discussed here, and is of the same order of magnitude for all cars. These motions tend to be periodic; in fact, on most roads they seem to be of small importance except in vehicles that tend to have a distinct resonance period in pitching. The physiological effects of this sort of motion may be of considerable importance

(6) Disregarding the centrifugal effects discussed above, the rotations that accompany changing direction impart very small reactions on the occupants of a vehicle and, since these are almost independent of the design of the vehicle, they hardly need further consideration here

Having pointed out some of the types of vehicle reaction that may irritate or tire the passengers in greater or less degree, it is pertinent to ask what can be done about it. In the first place, it seems that we should have a satisfactory means of observing and recording the actual characteristic motions of different vehicles on the usual types of road. This would mean a record of the motions or the accelerations or, better still, of both of them, with reference to all of the six degrees of freedom mentioned above, or at least the first five of them. A number of reasonably successful instruments that have been produced give some of this information, but, so far as we know, none of them gives it all at one time. An ideal instrument for this purpose should be capable of occupying the place of a passenger on the upholstery of a seat, as well as of being rigidly attached to the body of the vehicle. It should be easily transferable from car to car, and should require a minimum of attention.

Having secured a record of the sorts of motion to which a passenger is subjected, the next step would be to find out, if possible, which motions are most irritating and which least irritating or fatiguing to the average person. It is likely that the problem could be attacked after the manner of the experimental psychologist by laboratory methods. A "torture chair" could be designed to reproduce and repeat any type of motion, once we had some suggestion as to what sort of motion to try.

One suggestion along this line comes from the general experience of the biologist and the physiologist. This is that human beings, in common with other animals, usually, if not always, tolerate those conditions to which their race has been subjected during the process of evolution and are likely to be intolerant or very adversely affected by conditions even a little outside the range of racial experience. A suggested application to the question in hand, which may not have the slightest significance, is as follows: vertical accelerations and shocks are natural every-day occurrences in the life of the individual. Every step constitutes a vertical shock along the vertical axis of the body; hence we might expect that vertical motions would not be particularly fatiguing. On the other hand, sudden horizontal accelerations are not by any means common. It is possible, therefore, that these components in the forces to which the occupant of a vehicle is subjected might be proved to be of considerable importance in the fatigue they produce.

So far as the mechanical nature of the forces discussed above is concerned, there appear to be two classes into which they may be divided, although the division is rather arbitrary. They are

(1) Those forces of such short duration or corresponding to motions of such small amplitude that they affect only the surface of the body and do not react on its system as a whole. The effect of these should be reasonably independent of the direction in which they are applied, whether horizontally or vertically, although their effects on different parts of the human body may be very different

(2) Forces of longer duration which have an effect on the entire system, probably depending very much on the direction in which they are applied

Looking at the whole problem in a general way, it appears that the advance which has been made in riding qualities has been very largely a matter of natural selection. There are not even yet any entirely satisfactory principles of design that apply specifically to comfort of riding. It seems that such general principles might be developed through systematic research. The problem is one, the solution of which should appeal to some of our universities and technical-school laboratories in view of the several distinct phases that could be taken up more or less independently and of the opportunities it offers for training in applied mathematics and analytical mechanics.

[4] See THE JOURNAL, June, 1922, p. 463.

WORK OF THE 1922 STANDARDS COMMITTEE

THE acceptance of the reports of the various Divisions of the Standards Committee at the meeting on Jan. 9, 1923 will complete the work of the 1922 Standards Committee of the Society. The personnel of the 1923 Standards Committee will be appointed at a meeting of the Council to be held during the Annual Meeting. As, from year to year, a large majority of the Standards Committee members are reappointed, the 1923 Divisions will be able to carry on the current work of the Divisions without any loss of time or interest.

As at present organized, the Standards Committee consists of 9 automotive and 18 parts and materials Divisions as listed below.

AUTOMOTIVE DIVISIONS

Aeronautic Division	Motorboat Division
Agricultural Power-Equipment Division	Motorcycle Division
Electric Vehicle Division	Passenger-Car Division
Isolated Electric-Lighting Plant Division	Stationary-Engine Division
	Truck Division

PARTS AND MATERIALS DIVISIONS

Axle and Wheels Division	Non-Ferrous Metals Division
Ball and Roller Bearings Division	Parts and Fittings Division
Chain Division	Passenger-Car Body Division
Electrical Equipment Division	Radiator Division
Engine Division	Screw-Threads Division
Frames Division	Springs Division
Iron and Steel Division	Storage-Battery Division
Lighting Division	Transmission Division
Lubricants Division	
Nomenclature Division	

As indicated by their names, the Automotive Divisions represent the various automotive industries and the Parts and Materials Divisions the various parts and materials industries supplying one or more of the automotive industries. The total membership of the 1922 Divisions and Subdivisions is 419, the Division members numbering 293; and the Subdivision members 274, of whom, however, 148 are also members of one or more of the Divisions. Over 90 Subdivisions were appointed during the year to handle the more important subjects before the Divisions.

The work involved in the formulation of the Division reports may well be appreciated from the fact that 46 Division meetings and over 15 Subdivision meetings were held during the year. The number of Subdivision meetings is not definitely known as many are called by the Subdivision chairman instead of by the Society office as in the case of Division meetings.

Although the Division reports submitted at the June meeting of the Standards Committee and the reports appearing on p. 529 of this issue, which will be acted upon at the January meeting of the Standards Committee, represent the completed work of the 1922 Standards Committee, a large number of other subjects have been under consideration during the year. Many of these subjects were being studied prior to the life of the present Standards Committee, their nature being such that it has been found impossible to approve definite recommendations at this time. Other subjects have only been assigned to the different Divisions recently.

The accompanying list of the subjects that have been assigned to the various Divisions of the Standards Committee is therefore given in order that the members may appreciate the large amount of work in progress and ascertain if any of the subjects are of special interest to them. Reports as to the progress on these subjects are published in the monthly articles on current standardization, but the Standards Department stands ready to supply anyone with more detailed information if desired. The majority of subjects listed have been referred to Subdivisions, the chairmen of which will be glad to receive any suggestions or assistance in connection with their work.

Subsequent to the consideration at the Standards Committee meeting of the definite Division reports, printed on p. 529 of this issue, progress reports may be submitted by Division chairmen on some of the more important subjects among those listed hereinafter.

Although 51 subjects have been assigned to the Aeronautic Division, they are not listed herein as conditions in the aeronautic industry have not warranted recent standardization activity.

AGRICULTURAL POWER-EQUIPMENT DIVISION

Tractor Belts and Pulleys	Tractor Rating
Tractor Plowing Speeds	Tractor Testing Forms

AXLE AND WHEELS DIVISION

Brake-Drums	Differential Gears
Wire-Wheel Spokes	

BALL AND ROLLER BEARINGS DIVISION

Annular Ball Bearings, Wide Type	Roller Bearings, Metric Type
Roller Bearings, Inch Type	Shaft and Housing Fits and Tolerances
Thrust Ball Bearings, Inch Type	

CHAIN DIVISION

Roller Chains	Roller-Chain Sprocket-Cutters
Roller-Chain Sprockets	

ELECTRIC VEHICLE DIVISION

Battery Trays for Electric Trucks	Lamp Bulbs for Electric Vehicles
Charging Plugs and Receptacles	Storage-Battery Tray Terminals

ELECTRICAL EQUIPMENT DIVISION

Automobile Wiring	Generator Through-Drive Shafts
Cable Clips	Insulated Cable
Cable Terminals	Magnet Wire
Flexible Conduit	Rubber Bushings

ENGINE DIVISION

Crankcase Drain-Plugs	Motorcycle Carbureter Flanges
Engine Numbers	Poppet Valves
Engine Testing Forms	Starting-Cranks
Fan-Belts and Pulleys	

FRAMES DIVISION

Motor-Truck Frames	Passenger-Car Frames

IRON AND STEEL DIVISION

Cast Iron	Sheet Steel
Chemical Compositions	Specification Numbers
General Heat-Treatments	Structural Steel Tubing

LIGHTING DIVISION

Bases, Sockets and Connectors	Lamp Glasses
Focusing Mechanisms	Motorboat Lighting Equipment
Tail-Lamp Illumination	

LUBRICANTS DIVISION

Cup Grease	Transmission Lubricants

MOTORBOAT DIVISION

Engine Testing Forms	Engine Couplings
Exhaust-Manifold Connections	Nomenclature
Control Levers	Tachometer Drives
	Trial Performance Forms
Stuffing-Boxes	

NOMENCLATURE DIVISION

Aeronautics
Highway Transport
Industrial Service
Motorcycling
Power Farming
Stationary-Engine Operation
Water Transport

NON-FERROUS METALS DIVISION

Brass Alloys
Bronze Alloys
Wrought Non-Ferrous Alloys
Specification Numbers

PARTS AND FITTINGS DIVISION

Brake-Lining
Cotter-Pins
Fuel and Lubrication Pipe-Fittings
Felt Specifications
License-Plates and Brackets
Radiator Hose
Wire Mesh

PASSENGER-CAR DIVISION

Brake Tests
Car-Performance Tests
Frame Numbers

PASSENGER-CAR BODY DIVISION

Body Nomenclature
Door Hinges
Nickel-Plating
Upholstery Leather Rolled Sections

SCREW-THREADS DIVISION

Bolts
Gages and Gaging
Rivets
Screws, Bolts and Nuts
Screw-Thread Practice
Tire Valves

SPRINGS DIVISION

Definitions
Leaf-Spring Nomenclature
Motor-Truck Springs
Passenger-Car Springs
Center-Bolts
Spring Specifications
Tests for Parallelism of Spring-Eyes

STATIONARY-ENGINE DIVISION

Connecting-Rods
Crankshafts
Piston-Rings and Grooves
Poppet Valves
Stationary-Engine Belt Speeds

TRANSMISSION DIVISION

Clutch Standardization
Clutch Facings
Transmission Tire-Pump Mounting

TRUCK DIVISION

Motor-Truck Rating
Power Take-Off Shaft-Ends

THE SOCIETY'S STANDARDIZATION PROCEDURE

IT is the function of the Society's Standards Committee to formulate, if feasible, standards and recommended practices that will simplify and coordinate routine and engineering practice on all subjects assigned to it by the Council. To facilitate the work, the Standards Committee is resolved into 27 Divisions, each being representative of a particular branch of the industry.

Personnel

The Standards Committee is presided over by a chairman and two vice-chairmen. Each Division has a chairman and one vice-chairman. The Standards Committee and Division chairmen are designated by the President of the Society, the other personnel of the various Divisions being appointed by the Council. In addition to the Division personnel, Subdivisions are appointed to formulate tentative reports covering important subjects that are under consideration, the Subdivision members being appointed by the Division chairmen. The Subdivision chairmen are usually members of the Divisions to which the Subdivisions report, but other Subdivision members are selected from the industries at large to assure the assistance of the best-qualified men in each particular field.

Members of the Standards Committee need not be necessarily members of the Society, such committee members being known as conferees and having all the privileges of regular committee members except that of voting. In selecting members of the Standards Committee importance is placed on obtaining men of broad experience and so far as possible familiarity with standards work. Many of them naturally are associated with the older and better-known companies, but they are selected for their personal qualifications.

Initiation and Procedure

The assignment of subjects to the various Divisions is generally based on requests that have been received from members of the Society or the industry directly affected. Subjects are not assigned by the Council unless their standardization is considered feasible as well as desirable. Upon assignment to the proper Divisions, the various matters are studied with relation to the limiting phases within which standardization can be accomplished and the probable requirements of the industry affected. If a subject is involved, the features that the standard should embody are outlined and an approval of the outline obtained from the companies interested. The industries are then circularized for data representing current practice and suggestions for consideration by the Division members. The information is then, as a rule, referred to a Subdivision for the formulation of a tentative proposal which, when submitted, is referred to the industries for comment. The tentative proposals, together with the comments received, are then referred to the Divisions, and revised to meet all valid objections which may have been made. The Division recommendations are then printed in THE JOURNAL prior to consideration of them at the next meeting of the Standards Committee.

Division reports may be approved only by the Standards Committee at regular meetings held semi-annually or at special meetings called by direction of the Council. These meetings are open to Society members and non-members alike. The reports are discussed and may be approved as submitted or in revised form or referred back to the respective Divisions for further consideration. After Standards Committee approval the reports go to the Council and if approved are acted upon at a regular business meeting of the Society. The reports may be amended at these meetings but are usually approved as submitted. The reports are then submitted to the voting members of the Society for adoption by letter ballot, a majority of the votes cast being necessary to make the recommendations official S.A.E. Standard or Recommended Practices. The results of the letter ballot are referred to the Council, and in case a recommendation encounters several negative votes supported by sound engineering reasons, the Council may withhold its publication in the S.A.E. HANDBOOK until the reasons submitted shall have been reviewed by the Division making the recommendation.

Although the regulations provide that a majority of votes

(*Concluded on p.* 560)

Motor-Vehicle Head-Lamps and Road-Lighting

By R. C. Gowdy[1] and J. G. Balsillie[2]

Illustrated with Photograph and Charts

SINCE headlight lenses and other dispersing devices mainly perform a secondary function in taking the light from a parabolic reflector and redistributing it and because more effective road-lighting is necessary to compensate for the increase in the average speed of driving and in the congestion of traffic, the authors state that a direct solution of the problem lies in modifying the reflector so that the light is distributed properly at its first reflection and lenses or secondary devices are rendered unnecessary.

The consensus of opinion of many motorists regarding the proper degree of illumination is stated and light-distribution experiments are described. Types of reflector and the amount of light-distribution desirable are discussed, an exposition being given also of the corrugated reflector and the merits and demerits of hyperbolic and parabolic basic curvatures. The subject of light concentration is given brief consideration.

WITH the rapid increase in the use of motor vehicles, the providing of adequate and safe road-lighting for night driving has become an acute problem. The acetylene lamp was displaced by electrical equipment because of the inconvenience of using acetylene, rather than on account of any lack in its efficiency, and the later developments have been the result of efforts to improve the utility of the electric devices.

So long as motor vehicles were few in number, the driver was the one principally to be considered, and the parabolic reflector with a bulb of high candlepower met his not too exacting requirements. But when an approaching vehicle ceased to be a rarity, protection from glare became necessary. Various types of shield and visor came into use, but these removed the difficulty only by removing half the amount of light and were not effective unless properly located for the particular focal adjustment.

The increase in the average speed of driving and the congestion of traffic demand some more effective lighting. To do this many forms of lens and other dispersing devices have been developed. Nearly all of these, however, perform a secondary function in taking the light from a parabolic reflector and redistributing it. It is clear that a direct solution of the problem lies in modifying the reflector so that the light is distributed properly at its first reflection and lenses or secondary devices are rendered unnecessary.

The development of the corrugated reflector, which accomplishes the purpose, dates from experiments that were begun in Australia some 5 years ago. The first problem was to find out what was required. The consensus of opinion of many motorists who were consulted showed that, as a general rule, they desired an illumination of the total breadth of the road at a distance of 50 ft. ahead of the vehicle, and that the light be distributed along the road from about 20 to about 150 ft. ahead. A simple sketch of such an illuminated road area shows that the cross-section of the beam of light must be decidedly elliptical, with a much greater horizontal breadth than vertical depth. This shape cannot be obtained from a reflector that causes the light to diverge as from a point, but some surface must be used that causes the light to diverge as if it were coming from a source elongated horizontally; that is, the reflecting surface must be astigmatic.

Light-Distribution Experiments

The effectiveness of this type of distribution was tried with some unexpected results. The projector used for the experiments consisted of a powerful light-source and two lenses, one spherical and the other cylindrical. With these two lenses a fan-shaped beam of light could be produced and the depth and spread could be varied by adjustment of the lenses relative to the source. The projector was mounted at a height of 4 ft. above a level road, and the apparatus tilted so that no rays were sent above lamp level. The apparatus was adjusted so that the roadway was illuminated for a distance of 150 yd. and, at this distance, for a breadth of 58 yd.

It was thought that, with this arrangement, road-illumination from a motorist's viewpoint would be perfect; but such was not the case. The sharp upper boundary of the beam cut-off the upper portions of pedestrians and vehicles, and the observer's eyes, being unaccustomed to such fragmentary appearances, were unable to recognize the obstructions properly. Another interesting effect was noticed, in that, when pedestrians walked straight away from the projector, distinct visibility for those behind the projector ceased at about 65 yd., although the pedestrian could still see clearly at that distance for an additional distance of 150 yd. When the road-light up to 65 yd. was dimmed by the use of screens, the range of visibility for observers behind the projector was increased to 170 yd. From this it was concluded that the light reflected from the brilliantly illuminated foreground produced a glare which interfered with the vision of an observer stationed behind the projector.

These experiments indicated clearly the general type of distribution that would prove successful, but they also brought out the danger attending the sharp upper cut-off of the beam. Clear resolution for the driver requires that the upper parts of vehicles and pedestrians be illuminated, but such illumination usually means that those approaching the light will be dazzled. A practical solution of this difficulty does not seem possible without elaborate optical devices. The best that can be done is to allow as much light above the lamp level as can be had safely without blinding those who approach.

Many experiments have been carried on, both in this Country and abroad, to determine the intensity of light that produces glare. Estimates by various observers differ widely, but it is significant that observers who permit an abnormally high intensity without experiencing glare are usually found to have astigmatism. When this

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[2] Director general of the radio telegraphs for the Australian Government, Melbourne, South Australia.

error is present in the eye, a point source of light is not focused sharply but is spread into an elongated spot in the direction in which the defect occurs. Conversely, for a normal eye, an astigmatic source or one from which the rays appear to come from an extended region, may not produce glare at a given intensity when a point source of the same apparent intensity does produce this effect.

Types of Reflector

With these experimental facts as a basis, the original corrugated reflectors were made by forming a parabolic reflector with fine vertical stripes, using 12 or more per in. Each of these small stripes was considerably curved in section to produce the necessary spreading of the light. The very large number of beams projected by such a reflector causes a soft diffusion of the light and practically eliminates glare. Reflectors of this type are much in use abroad but, until the present, they have not been available in this Country because of our more strict legal specifications and certain difficulties attending quantity production by American methods. After more than a year of intensive research, development and experimentation, these difficulties have been overcome and the American model of the corrugated reflector, illustrated in Fig. 1, has gone into production.

In adapting the principle of corrugation, two points must receive consideration; first, that the distribution of the projected light comply with the strictest legal requirements in force in any State and, second, that a satisfactory driving light be produced. At present, the specifications adopted by the Illuminating Engineering Society and the Society of Automotive Engineers seem to be at once the most exacting and the most generally adopted for the control of roadway illumination. These specifications stipulate the apparent candlepower that must be provided in certain angular directions in front of the vehicle. Their purpose is to insure adequate light and, at the same time, to prevent excessive glare to approaching machines or pedestrians. It does not follow, however, that a headlight that complies strictly with these regulations will necessarily provide satisfactory road-light or be free from glare, since the desirability of a light depends upon many other considerations than simply its candlepower at a few specified points, and the sensation of glare is not due simply to high apparent candlepower, but also depends upon the illuminated area that is responsible for this apparent intensity. The specifications mentioned are perhaps the best that have yet been produced and, although they probably will be subject to some slight modifications in the future, they provide a fairly satisfactory code for testing lighting devices of widely differing types. It has been our experience, in testing many different designs of reflector and lens, that those which provide a satisfactory road-light do as a rule comply with these specifications, although many devices that do comply strictly with these requirements are not altogether satisfactory.

Desirable Light-Distribution

It has been found that there is a wide difference of opinion as to what distribution of light is most desirable for road-lighting. This difference of opinion arises from three sources, the idiosyncrasies of the driver, his habitual speed and the character of road upon which he generally drives. Some drivers prefer the light near the vehicle and some prefer it at a greater distance, some prefer a very wide spread of illumination, and others are content with a narrower pathway. A light that is satisfactory on a white road will be found entirely inadequate on a dark surface, and any road presents an extremely difficult problem of illumination when it is wet.

A light that is satisfactory for low speeds will be found unsatisfactory at high speeds, and it seems improbable that sufficient light can be provided for safe driving at speeds greater than 30 m.p.h. without the use of such powerful beams that glare is almost sure to result. After many experiments we have found that about 25 deg. of horizontal spread meets with general approval, that more than 20,000 cp. is necessary in the center of the beam and that smoothness of distribution and absence of any sharply defined bright areas are of greater importance. A sufficient length of road for average conditions will be illuminated by a beam that has a vertical depth of 6 to 7 deg. in the center and 3 to 4 deg. toward its sides. For the protection of the on-coming driver and pedestrian, it is essential that the cut-off across the top of the beam be curved downward at the side and, since the driver generally desires the light to come nearer the vehicle in the middle of the road than at the sides, this same contour is most satisfactory for the bottom of the beam also.

As a result, it appears then that the ideal beam should be somewhat elliptical in shape with a gradual increase in its candlepower toward the center. So far as the driver alone is concerned, it would perhaps be more desirable to throw the maximum candlepower near the top of the beam where it would be effective at a greater distance from the vehicle; but such a distribution is dangerous for the on-coming driver, since the pitching of the vehicle will then throw this high intensity above the lamp level and cause blinding flashes in the eyes of those approaching. It seems advisable, therefore, to protect the on-coming driver at some slight expense in distant road-lighting.

Corrugated Reflectors

The development of corrugated reflectors began with the configuration of parabolic surfaces. If a point source be placed at the focus of a simple paraboloid such as is commonly used in headlights, a beam of parallel rays of the diameter of the reflector would be projected. With a source of finite size, such as the filament of a lamp bulb, it is no longer possible to obtain a parallel beam, but the reflector will project a divergent beam whose spread depends on the size of the filament. The filaments in use at present produce a cone of rays of about 4-deg. divergence.

If the paraboloid be corrugated, the light from each corrugation will be spread into a broadened cone, but the spreading will occur only in the plane at right angles to the corrugation; that is, if the corrugation is vertical, the light reflected from it still will have the same vertical depth of beam that would be projected from the corresponding portion of the simple paraboloid, but horizontally the beam might be distributed over a wider angle. Such a beam is astigmatic; the rays that compose it diverge, not from a point, but from an elongated image of the source. All the corrugations on a parabola throw overlapping fan-shaped beams, the centers of which register one over the other.

The amount of horizontal spread that will be produced by a given corrugation depends upon its width, curvature and distance from the source and, if the width be chosen arbitrarily, the distribution of the light projected by the reflector still can be controlled by the curvature of the stripes. The width of the stripe will be chosen for appearance, ease of production and control of diffused light since, in general, the larger the number of stripes is, the greater the amount of light diffused

from them will be. The stripes can be made either concave or convex, as convenience of design or manufacture may demand. If the corrugations are convex, the light reflected from them will be diverging; if concave, the curvature may be chosen to give either continuously diverging beams or beams that first converge and then diverge.

The distribution of light obtained with the concave stripes that give convergent, diverging beams is shown in the photometric chart, reproduced in Fig. 2. This chart shows the apparent candlepower at the various points in the field. The point *A* is at lamp level and directly in front of the vehicle, and the other points are located by their *angular* positions as they appear when looking forward from the vehicle. The contour lines in the left half of the field are lines of equal candlepower of the values 1000, 2000, 5000 and 15,000 cp. respectively. This reflector gives a very intense beam with 15 deg. of horizontal spread. Such a distribution is favored highly by those who are accustomed to drive at high speeds on dark-surfaced roads, but is not particularly desirable for city driving, nor on rough roads where the speed must be

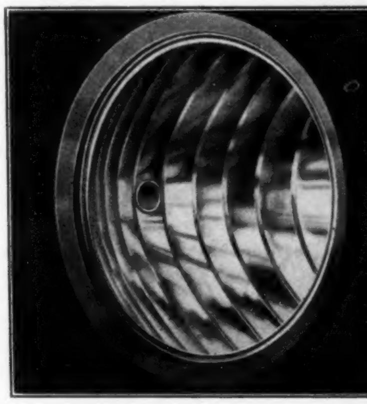

FIG. 1—TYPE OF CORRUGATED REFLECTOR PRODUCED IN AMERICA

reduced and the pathway continually shifted. Many other designs embodying stripes of various widths and curvatures were prepared and satisfactory road-lighting was obtained, but it was found that all of these reflectors had very critical focal adjustment and generally insufficient vertical depth of beams. The critical focal adjustment and the lack of vertical depth are inherent defects of the parabolic form as a basic curvature for the reflecting surface. The vertical spread from the parabola is due entirely to the fact that the filament of the lamp has finite size, and the top and bottom of the beam are projected by the central portion of the reflector, while the center of the beam comes from the outer portion of the reflector. Any displacement of the filament affects the outer portions of the beam very much more than it does the center of the beam, since the change in angular position of the filament with respect to the center of the reflector is greater than the corresponding change for the edge of the reflector. Consequently, any displacement of the lamp will greatly affect the cut-off of the beam, and any irregularities near the apex of the reflector will tend to produce undesirable stray rays. To obviate these inherent difficulties of the parabola, the basic curvature of the reflector was changed to the hyperbolic form. The hyperbola permits much greater flexibility of design and affords a greater control of projected light.

HYPERBOLIC VERSUS PARABOLIC REFLECTORS

The hyperbolic surface projects a divergent beam. Its divergence is determined by the major axis, the focal

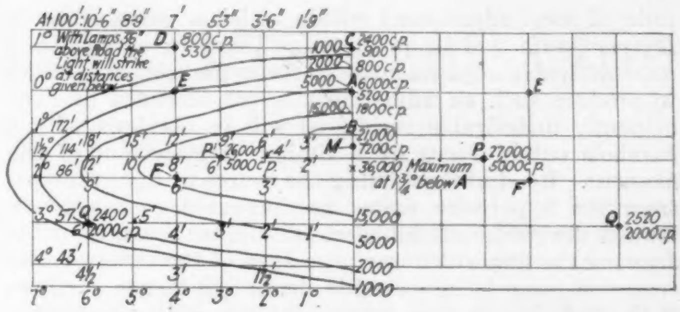

FIG. 2—PHOTOMETRIC CHART SHOWING THE DISTRIBUTION OF LIGHT OBTAINED WITH THE CONCAVE STRIPES

Where Three Sets of Figures Are Given for a Point the Middle One Is That Obtained in the Test While the Upper and Lower Figures Represent Respectively the Maximum and Minimum Called for by the Lighting Specifications. Where Two Figures Are Given the Upper Figure for Points Above the 0-Deg. Line and the Lower Figure for Points Below This Line Indicate the Requirements of the Specifications. The Other Figure in These Cases Represents the Value Obtained in the Test

length chosen and the diameter of the reflector. In the hyperbolic reflector the axial rays are projected by the central portion of the reflector and the more divergent rays by the outer portions in succession to the edge of the reflector. In the parabolic reflector all of the stripes throw the beams that register almost exactly, one over the other, while in the hyperbolic reflector there is a displacement of the beam from each successive stripe to the right and left. This failure of the beams to register causes a patching-up of any irregularities in distribution rather than their accentuation, as in the case of the parabola. The shape of the cut-off from the hyperbolic reflecter is essentially elliptical, but minor alterations in form and in the distribution of the light laterally can be obtained through proper curvature of the stripes. As has been mentioned, the control of the distribution at the top and bottom of the pattern is more readily obtained with the hyperbola than with the parabola, since these regions are affected by the end portions of the stripes rather than the center portions, and these end portions are more readily controlled in manufacture than the center of the reflector.

The hyperbolic forms chosen for the standard sizes of reflector have the same diameters as the parabolas and are slightly shallower and of somewhat shorter focal length. The focal length is shortened from 0.03 to 0.04 in. to make the hyperbola conform to the standard dimensions of lamp bodies. Curiously enough, these hyperbolas are somewhat similar in shape to parabolas of slightly greater focal-length than the standard parabola. Hence, a solid beam of light will be projected from a source placed anywhere between the actual hyperbolic focus and the focus of a parabola of similar dimensions. This means that the device possesses considerable lati-

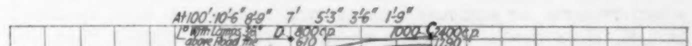

FIG. 3—CHART GIVING THE RESULT OF TEST MADE WITH A HYPERBOLIC REFLECTOR

Where Three Sets of Figures Are Given for a Point the Middle One Is That Obtained in the Test While the Upper and Lower Figures Represent Respectively the Maximum and Minimum Called for by the Lighting Specifications. Where Two Figures Are Given the Upper Figure for Points above the 0-Deg. Line and the Lower Figure for Points below This Line Indicate the Requirements of the Specifications. The Other Figure in These Cases Represents the Value Obtained in the Test

tude of focal adjustment within which a passabiy satisfactory beam will be projected. There is, of course, a most desirable adjustment with the hyperbola, but failure to produce such an adjustment is not attended by such evidently undesirable results as will be obtained with a parabola out of focus by a similar displacement of the filament. By slightly shifting the source of light forward from the hyperbolic focus, an increased concentration toward the center of the beam is obtained; and, by withdrawing the filament toward the apex of the reflector, the projected beam is increased in depth and larger portions of the light are thrown toward the top and bottom, producing a more uniformly illuminated pattern. Throughout this range of adjustment, the general shape of the cut-off is not altered nor are any undesirable stray rays produced. Thus, within certain limits, the user can produce the type of distribution that best suits him by a slight alteration of the focal adjustment of the lamps, while the essential requirements of legal specifications are fulfilled within these limits of adjustment. A characteristic chart for the hyperbolic reflector is shown in Fig. 3.

Light Concentration

It has been found by experiment that the concentration necessary for the illumination of dark-surfaced highways cannot be obtained readily with a series of stripes of uniform and circular curvature. The production difficulties attending the use of special contours in the formation of the stripes make it inadvisable to depart from the circular sections where curvature is required. The problem of obtaining a sufficient central light has been solved by the introduction of another series of narrower stripes that retain the basic hyperbolic curvature. By breaking up this hyperboloid surface into a number of narrow stripes, any contour surrounding the bright portion in the center of the light pattern is eliminated and a gradual blending from the high intensity in the center to the dimmer edges is thus obtained. Our experiments on the road have shown that an extreme smoothness of distribution and a gradual change in intensity are of even more importance than actual candlepower, and a properly distributed beam will give the impression of much more light on the road than an improperly distributed pattern, even though its maximum candlepower may be very much higher, and any marked contours or patterns thrown on the road always prove distracting when the light is shifted by the jostling of the vehicle.

It is pointed out that the reflector has a decided and inherent advantage over any lens in that the light coming directly from the lamp without reflection is free from the streaked appearance that all lenses produce near the vehicle. This is, of course, of little importance in driving, but is of marked advantage when parking the machine at the curb, because the side light near the vehicle shows uniformly and produces no illusion of irregularities such as may often be occasioned by the directly refracted rays through lenses.

THE SOCIETY'S STANDARDIZATION PROCEDURE

(*Concluded from p.* 556)

shall be necessary to approve a recommendation, a recommendation is seldom approved unless the action is practically unanimous. The reasons for this are patent, as well-founded objections to any adopted recommendation would militate against its general reduction to practice, resulting in a "paper standard" only.

The time required for the stated procedure varies from 3 months to in some cases a number of years, depending upon the conditions involved. A large amount of office work is required in corresponding with the industries and members of the Divisions, arranging meetings and keeping progress records.

S.A.E. Handbook

Subsequent to the Standards Committee meeting, the revisions of the reports together with the discussions thereon are printed in the following issue of The Journal, the revised reports as approved being printed in the next issue of S.A.E. Handbook of data sheets. It is essential that all standards be published in a clear, concise and uniform manner. This was recognized in the beginning by the pioneer members of the Society and its Standards Committee, and the present well-known loose-leaf S.A.E. Handbook has proved the wisdom of selecting this form of publication. Clear detailed drawings with tables and notes are used to set forth the standards and recommended practices. A complete set of the standards goes to all the members of the Society, including the new and revised standards issued twice a year. The complete Handbook is available to nonmembers of the Society and a single copy of any standard may be obtained upon request to the Society. The standards are not copyrighted, but it is expected that the Society will be given due credit for any of its data reprinted in other publications.

The procedure of revising existing standards is the same as when the subjects are originally considered. As such revisions are not published in the S.A.E. Handbook until they have been approved by letter ballot of the voting members and this procedure usually takes several months, it is well for all interested to ascertain whether a standard is under revision in case production on a design involving the use of a S.A.E. Standard is contemplated. Complete information in reference to the current work of the Standards Committee is published regularly in The Journal.

The Production Man's Place in Our Industry

By A. B. C. Hardy[1] Detroit Production Dinner Address

THERE is more than passing significance in this two-day session, the first National Production Meeting of the Society of Automotive Engineers; that is, the first national production meeting of our great automotive industry. What is more natural than that in this meeting we should discuss the production man?

In getting at him and his place in our industry, I believe it may be not only permissible, but illuminating, to list in their natural order of operation the six main line divisions of automotive organization at the plant.

Given an automobile company, a plant and management, come then:

(1) Engineering: Designing, experimenting
(2) Purchasing: Buying, releasing and follow-up
(3) Production: Manufacturing, inspecting, assembling and testing
(4) Selling: Advertising, sales, service
(5) Traffic: A double service; inbound, to serve between purchase and production; outbound, to serve between the sales department and the company's distributor and dealer customers
(6) Accounting: A multiple service, serving all of the other five departments, as well as the stockholders and the management; estimates; costs, direct and overhead; accounts; credits, collections, disbursements and records of results

These six divisions of work, with a reasonable amount of general management sandwiched in between, make up the average central operating organization. One cannot help but note that five of these six main divisions of the work are almost self-defined by their titles.

Engineering, presenting the design charted in blueprints backed by data and records of tests and opinions of other engineers, paints and sells the picture to the "Old Man," the Committee or the Board, with enthusiastic assurance that it is so real a picture that the public can be depended upon to joyfully furnish the gold to frame it. And if the "Old Man," be he 25 or 50 years of age, buys the picture, we all clearly vision just what purchasing, selling, traffic and accounting proceed to do as their part of the work.

But production? Of course we can say, "Why, that is the manufacturing end of the business," and let it go at that. But it is a broad field and the outlines of its territory, its authority and its responsibilities are not so easily defined. We do note, however, that this production or manufacturing division of the work requires and occupies 80 to 90 per cent of the acres of land and 70 to 80 per cent of the acres of floor-space which the sales and advertising departments boast of, and that it requires and directs the work of 5, 10 or even 15 times the total number of people required by all the other divisions combined. It needs and uses more kinds of people, that is, people in more kinds of trades and training, than all the other five divisions combined.

To head, direct and lead the leaders of the many departments, trades and groups, appears The Production Man, *The Real Manufacturing Man,* whose place in our industry we are discussing. Before attempting to define his status in the industry, let us see what the production man must know, or know about, at least in a general way, to qualify for his job. He must, above all, be a good judge and a just judge of men and a fair and square man himself. He must be strong enough to play no favorites. Surely he must know the general labor conditions in the many subdivisions of his own industry, as well as in kindred or related industries, whether his factory be next door to the factory of its strongest competitor or hundreds of miles from it. He must at all times know the basic rates and changing labor conditions in his own city and the general sentiments of his city. He must know in a general way about day-work, piece-work and group-bonus systems, as he is the first man that we have to sell any new rating-system; he in turn must help sell it to his department-heads and they in turn to their employes. And he must know in a general way the results expected from each one of these systems.

He must have at least general knowledge about plant layout and plant construction. He must know generally much more about machinery, plant equipment, electric equipment, power transmission, patterns, tools, jigs, dies, fixtures and supplies; about ovens and methods of heating them by gas, electricity or oil burning. He must know generally about electricity for power and light, and about air-compressors and air transmission, steam power and heating, steam fitting, plumbing and sanitation.

Materials

The production man must know something about the nature of castings—steel, gray iron and malleable; brass, bronze and aluminum alloys, from foundry into machined, finished and assembled parts; forgings and their machining; heat-treating, hardening, grinding and the like; sheet metals, through deep-drawing to stampings, and including nickeled, painted or enameled finish; woods of the various kinds and their working; fabrics, carpet and leather through their various automobile uses; paints and enamels and their processes and results; sub-assemblies, assemblies, finished units and complete-car assemblies and tests; and inspections, yes, endless inspections, from the receiving doors on through to the finished automobiles.

The production man must respond in his work to the service information from the field. In addition, he must be the type of man who can "steady" and lead in a crisis, when serious accident, a fire or a strike comes. Moreover, he must in some way keep in touch with and in sympathy with welfare work and the living conditions of the employes.

Training of Production Men

No small order, is it? And I have only touched the high spots. Is there any such man? Or, rather, are there any such men? There are, and more of them are coming up through the same long tedious but fascinating and always-changing courses of the automobile factory

[1] M.S.A.E.—President and general manager, Olds Motor Works, Lansing, Mich.

experience-schools. No college and no school can hope to deliver any such man as a finished product, ready to function. The colleges may be able to give to young men a start on such elements of the science of production work as are definitely recorded at the time the young men are coming through, and it is to be hoped that the schools will be frank enough at the close of their courses to apprise their young men of the truth, the fact that the theoretical or school course has only shown them how to begin to start over again by entry in the regular way past the employment window of the plant into the only real course, a stiff one and a long one, but the most inspiring and fascinating production course. It requires guts as well as brains. The place to look for the coming production man is back along the lines in your plants and in ours, for that is where the production man of to-day came from.

Is this production man, who must know broadly about so many things, a super-man? Not at all; and, fortunately for him and for the industry, he has never been touted as such. And does he do the work or even direct it alone? Not at all; no one accomplishes anything alone in our complicated and fast-moving industry. The fact is that his specially trained assistants and department-heads, from the plant engineer, who keeps the physical plant in sweet running-condition, on through the divisions, to and through those who conduct the final car-test and inspection, after which the product is turned over to the traffic department ready to ship, carry their share of the load and responsibility. And the production man, their leader, if he be a wise man, is always on the lookout in his own plant, and also takes a side-look into other plants, your plants, to seek out the production talent that is being developed, to help him with the work in hand; by going around his job so as to look in at it from the human or employe angle, from the service or customer angle, from the plant and machinery angles, from the material and finished car angles.

Production Man's Status

I wonder if we have not shown pretty clearly the status of the production man. And it is "some status" now. He not only uses most of the land, plant, machinery and equipment but constantly demands more, and that he be allowed to assist in their selection. He influences and controls most largely the hiring and firing, which means the pay rates or incomes and the working and living conditions of far the largest number of people on the job. He and his department-heads are the means of conveying to the workers the standards and character of the company. And the workers judge the company accordingly. He and his department-heads and inspectors affect, almost more than they realize, the future of the company and its success, by the manner in which they build, test and inspect every element in the car and the finished car itself.

As to his importance in the industry, he is not much concerned; for you and I and he know to which department the head of the house, the Committee or the Board naturally turns when there is a mess, a mix-up or a big job at hand. Perhaps the production man has been too backward in making himself known. But he has been too busy on the job. Besides, the spot-light was focused elsewhere, turned first on the engineer or designer with the great idea, then on the promotion engineer, next on the commercial promoter, and then on the star manager or sales campaigner, all of whom made good publicity during the rapid expansion of the industry.

But at length, while the production man was being ground and polished through the mill, the real bosses of all our jobs, the motor-using public, began to control the spot-light and to throw it no longer upon individuals nor upon any one or few departments, but upon what we all as organizations did to them; upon our product, our car; and upon the organization behind that car, as a whole. Our bosses, who have found out that there are few mysteries, and that personal names and reputations perform no miracles and make no cures, will hold this spot-light mercilessly upon us all, not as individuals, but as organizations, and upon our product.

If the question, Production versus Design, as to importance to our industry, were put up to us, I for one should have to vote for production, because I have seen some poor designing turned into fairly good cars by production work and refining, and because those companies and cars that have had the best production or manufacturing attention are strongest and safest to-day. I may be prejudiced, as I have lived so many years with production, buying, selling, and with the men on the job.

But why raise such a question? It is too late. The public, our friends and customers, is not interested in it. The public has come to realize that the individual and independent transportation units which we together as organizations design, produce, sell and service are the things most needed by them after food, clothing, fuel and housing; even more than the telephone. You cannot imagine any individual family or corporation that needs and uses the telephone, getting along without the automobile, but you know of many who must have and do use automobiles and get along some way without the telephone.

Cooperation in Production

Through the medium of the Society, the designing engineers have been able for years to cooperate extensively. This cooperation, augmented ten-fold by the necessities and pressure of the war, standardized many materials, parts and practices, thereby simplifying construction and making vast savings for the industry, its material suppliers and the car-owners. Production engineers, unfortunately, have been denied the opportunity of cooperating with each other to any extent, because only the largest companies felt justified in training and maintaining all-round men; most of the production engineers of to-day are trained only in very limited and specialized fields. In addition, the automotive industry had been so grievously disappointed by the work of the early so-called efficiency and economy experts and groups, brought in from other industries, that it has not looked with general favor upon production engineering until recently. However, dodging the word efficiency, which was in disrepute, practically every plant of any size now maintains a reasonable amount of production engineering as a Standards or Planning Department or Production Office. It is only to-day, when its commercial age is fully 21 years, that our own great automotive industry which, with the related industries producing tires, parts and accessories, constitutes the Individual Transportation Industry, the largest combined industry in the world, is holding with you its first national production meeting. So, our production engineers can take heart with renewed patience and, if the Society has not already done so, should not its logical expansion open a Section for Production Engineers and possibly for Plant Engineers?

With cooperation in production engineering as now developed we believe that our designing engineers are considering more carefully the present and standard plant-machinery equipment in designing new product.

They must know that any new product, while in the paper and experimental stages, must be sold to the production department, to reflex the experience of the production man and his department-heads as to the makableness of the product; and sold to the service department as to the accessibility and serviceability in the field. Some of us have drawn engineering and production into closer and constant cooperation by a combined engineering and manufacturing committee, consisting of general manager, assistant general manager, chief engineer and manufacturing manager; and by calling into their meetings from time to time the sales or service manager or field-service engineer or manufacturing department-heads we may hope to stop the "passing of the buck," and to make our organization so closely woven a production fabric that *we shall all become real production men on the one Job.*

We know that this way lies permanence and success.

THE CENTRIFUGAL PROCESS OF CASTING IRON

IN a digest[1] of a paper on Centrifugal Castings, presented before the West of Scotland Iron and Steel Institute by F. E. Hurst, new evidences of progress in this method are indicated and these are also commented upon editorially.[2] The process, as at present operated in the Scottish plant with which the author of the paper is connected, is being applied to cast iron for producing large-size castings for piston-ring sleeves; gas, oil and Diesel-engine-cylinder liners; chilled wheel and chilled-roll castings; and cylindrical castings of all descriptions. The machines at present in operation are capable of producing castings up to a maximum length of 36 in. and of varying diameters from 10 to 30 in., and other machines for producing both smaller and larger castings are under construction.

The principle of operation of the centrifugal casting process lies in the introduction of molten metal to the mold or die while it is rotating rapidly about a horizontal axis. No core is used for cylindrical articles and a perfectly cylindrical interior surface is produced directly because of the centrifugal force exerted while the molten metal is solidifying and due also to the rate of introduction of the metal to the mold.

The centrifugal casting machine consists essentially of a faceplate mounted on a shaft carried in bearings arranged to be rotated at the speeds required. The molds are attached to the faceplate by bolts and, when rotating, the molten metal is introduced by tilting a specially designed pourer that has been moved into position inside the rotating mold. The molds themselves are constructed in two parts: An outer holding casting that is arranged to bolt to the faceplate, and an inner liner that is arranged to fit loosely inside the holder casting. The liner is bored internally to the size and dimensions of the outer surface of the casting to be produced, and the outside of the liner is bored to fit the holder casting, which is designed to take a group of a series of liners, the dimensions of which are arranged to produce flanged cylindrical castings of a standard series of dimensions. By this means the cost of the renewals of dies for the production of a given size is reduced considerably and, as a rule, the series of holders will take most of the special liners that are required for the production of castings of special shapes.

[1] See *The Iron Age*, Aug. 31, 1922, p. 529.
[2] See *The Iron Age*, Sept. 14, 1922, p. 666.

The back end of the liner next to the faceplate of the machine is closed by a plate attached to the end of a threaded rod passing through the hollow shaft of the machine and arranged for the ejection of the castings. The front of the liner is closed by an annular plate having the internal diameter of the annular ring corresponding to the internal diameter of the casting to be produced. This plate is arranged so as to be removable after the completion of the casting operation and allow the casting to be extracted.

As indicated, a series of standard dimensions of flanged cylindrical castings has been compiled, and the installation of the necessary holders and liners to produce these makes it feasible to manufacture a wide variety of cylindrical castings within the limits of dimensions specified and with alterations that are comparatively trifling. For example, the only alteration to the die required to produce castings thicker than a given standard is an alteration to the diameter of the inner circle of the closing plate. Castings shorter than the standard range of size can be produced by an alteration in the position of the ejector plate. Castings having specially shaped flanges or external projections require a special liner, but in the majority of instances a special liner only is required and the expense is not necessarily prohibitive. Castings having internal projections, or closed cylinders, or dish-shaped castings, cannot be produced on a commercial basis as yet.

Observation of the mechanical properties of centrifugal castings should always be made in conjunction with the chemical composition, and this must be taken into consideration when making comparisons between centrifugal and sand castings. So far as the investigation of the properties of centrifugal cast-iron has gone, in all cases a distinct improvement in the mechanical properties has been found. An improvement would be expected on account of the use of a metal mold, although there is no doubt that the centrifugal method itself has considerable influence in modifying the properties of the cast-iron.

In the plant mentioned an improved melting-furnace has been installed to supply hot metal of uniform composition, which is of prime importance in producing high-grade castings from low total-carbon mixtures and steel mixtures.

In the editorial comment already mentioned[2] it is stated that it seems evident that there are great possibilities in the application of the centrifugal process to small castings of suitable section.

Activities of the Sections

Schedule of Sections Meetings

DECEMBER

6—MINNEAPOLIS SECTION—Design Considerations in Pattern and Foundry Practice—R. C. Hitchcock
8—WASHINGTON SECTION—Piston Rings—A. W. Morton.
14—INDIANA SECTION—What Engineering Owes to Pure Science—John H. Hunt
14—METROPOLITAN SECTION—Air-Cooling of Automotive Engines—C. P. Grimes
15—BUFFALO SECTION—Results of Testing of Materials and Their Effects upon Present-Day Engineering—Prof. G. B. Upton
15—CLEVELAND SECTION—Troubles Encountered in Car Operation—A. J. Killius
19—DAYTON SECTION—The Utilization of Low-Grade Fuels in Automotive Engineering—P. S. Tice
20—MID-WEST SECTION (At Milwaukee)—100-Ton-Miles per Gallon—H. L. Horning and J. B. Fisher
22—NEW ENGLAND SECTION—Mechanical Service—Knox Brown
22—DETROIT SECTION—Body Engineering Meeting
28—PENNSYLVANIA SECTION—Aeronautics—Com. R. D. Weyerbacher, U. S. N.

THE Sections of the Society were very active during November, a total of 10 meetings being held. Attendance figures reaching the New York office reflect an increased interest in Sections meetings. It is also noteworthy that membership in the Sections shows an increase over that at the same season last year. The character of papers presented to date and the valuable discussions that have followed them are evidence of an advance in Sections activity. Read the following reports carefully and join the Section nearest you so that you may enjoy its future meetings.

CLEVELAND SECTION

Close to a hundred members of the Cleveland Section spent a very enjoyable evening on Nov. 17 listening to Dr. Georg Madelung's presentation of the analytical study upon which the design of the famous Hannover glider was based. This glider or sail-plane remained in the air over 3 hr., attained an altitude of 1000 ft. above its starting point and won all prizes in the Rhoen competition in Germany. Dr. Madelung stated that this fine performance was due to the application of fundamental aeronautic theory to the design of the glider so as to attain a minimum rate of descent. This enabled it to fly the longest possible time without losing altitude. Each of the factors in the formula determining the rate of descent was analyzed and by proper proportioning of the machine all of the variables were reduced to a minimum. This study indicated the importance of utilizing a long wing-span in combination with a short wing-chord or width. This was the outstanding feature of the machine from an aerodynamic standpoint. It had a span exceeding 40 ft. and the chord was approximately 4 ft. The weight was only 430 lb., including the pilot, yet the plane possessed great structural strength and rigidity.

It was evident to those hearing Dr. Madelung that the glider or sail-plane competitions have a distinctly valuable place in the field of aeronautics. The Rhoen meeting enabled the German engineers to test and prove the merit of several radical departures from conventional practice at remarkably low costs. Notable among these innovations was a landing gear consisting of three football wheels mounted on rigid axles; a monoplane wing with an unusually long span in combination with a short chord; a special thick-wing construction with only one wing-beam; and a plywood leading-edge construction designed to carry all of the torsional load on the wing. Dr. Madelung's paper will appear in an early issue of THE JOURNAL. It will convince every thinking engineer that glider experiments will exert a strong influenee on the aerodynamical features of the commercial airplane of the future.

The next meeting of the Cleveland Section will be devoted to a discussion of the troubles encountered by the average automobile owner in the operation of his car. The speaker, A. J. Killius, is service manager of the Cleveland Automobile Club. He has been making a special study of cars left for repairs at garages in Cleveland and plans to present a frank but constructive criticism of present-day automobiles from the service viewpoint. The meeting is scheduled for Dec. 15 at the Cleveland Engineering Society rooms, Hotel Winton, starting at 8 o'clock.

DETROIT SECTION

What Mechanical Men Should Know About Merchandising formed the subject of a very interesting talk given by E. S. Jordan before the Detroit Section, Nov. 24. Mr. Jordan, who is president of the Jordan Motor Car Co., made some very pertinent suggestions on the importance of engineers studying the demands of the automobile-buying public and creating features that will have a direct sales appeal. He urged a closer contact between the engineer and the salesman so that each might profit by the other's suggestions.

The next meeting of the Detroit Section is scheduled for the evening of Dec. 22 at the Detroit Board of Commerce.

MINNEAPOLIS SECTION

Piston-rings and pistons were the subject of two papers and a very thorough discussion at the meeting of the Minneapolis Section on Nov. 1. Allen W. Morton presented a well-prepared paper on piston-rings. He stated that multiple-piece rings are losing favor rapidly because of their greater liability to breakage, poor wearing quality in service and difficulty of installation. Individually cast rings are superior to pot-cast rings because of their uniformity, closer grained metallic structure, longer life and greater resiliency. Foundry practice of molding, melting and pouring is of greater importance than the chemical composition of the iron. Mr. Morton discussed methods of producing tension in rings and favored the practice that effects the result by artificial means such as peening, believing this assures better control of the final pressures on the cylinder-wall. He described a method of determining cylinder-wall pressures of rings by lapping a sample ring to produce rapid wear and then measuring the amount of ring wear at numerous points on the periphery. The importance of ring fit in the piston groove was stressed as a means of preventing oil-pumping. The discussion of the paper related to analysis of piston-ring iron, sticking of rings and ring thickness.

The second paper of the evening was read by George Bonthenon and set forth some practices followed by the author

in the manufacture of light-weight cast-iron pistons. Iron analysis, heat-treatment and machining operation data were given.

The next Minneapolis Section meeting will be held, Dec. 6, at the Builders' Exchange in that city. Motion pictures illustrating steel manufacture will be shown. Prof. Peter Christensen of the University of Minnesota, will give a descriptive talk on steel manufacture and R. C. Hitchcock will read a paper on Design Considerations in Pattern and Foundry Practice.

Metropolitan Section

About 50 members of the Metropolitan Section who attended the monthly meeting held on Nov. 14 at the Automobile Club of America, New York City, were entertained by a very comprehensive and instructive paper by Alden L. McMurtry, recently consulting engineer of the Connecticut State Motor Vehicle Commission, on the Regulations Governing the Use of Rural Highways.

The methods of investigating both the records of applicants for licenses and the causes of accidents were described in detail and were illustrated by numerous lantern slides. It was the speaker's contention that by penalizing offenders and by gradually weeding out the careless and irresponsible drivers good drivers would be protected and that speed limits, which are now the basis of legal restrictions, would be unnecessary. As the conditions under which a car is operated and the skill of the driver are usually the determining factors in accidents, a light passenger car traveling at a speed of 20 m.p.h. might be as dangerous as a heavier and better built vehicle at twice that speed. The importance of regulating the loading of trucks and of preventing overloading was emphasized.

David Beecroft in the discussion that followed said that highways were not built originally for present methods of transportation and were inadequate; that accidents for which the highways, rather than the drivers, were responsible would increase as the years go by; that lighting must be standardized throughout the Country, so that the same signal would not be indicated by two or three different colors in various localities; that at present there is too much light on passenger cars and not enough on trucks; that the highway lighting in vogue 40 years ago is still in use and is inefficient; and that the tendency of road hogs to hug the center of the road is due largely to the faulty illumination of the sides of the road. On account of the length of the paper very little time remained for discussion and members who wished to participate were requested to submit their comments in writing.

The report of the secretary showed that 51 new members had been admitted to the Section, making the present enrollment 254.

Air-Cooling of Automotive Engines will be treated in a paper by C. P. Grimes before the Metropolitan Section meeting, Dec. 14. Mr. Grimes is research engineer of the H. H. Franklin Mfg. Co. and consequently he speaks with authority on this subject. Metropolitan Section meetings are held at the Automobile Club of America, New York City, starting at 8 o'clock, and are preceded by an informal dinner at 6.30 p.m.

New England Section

The New England section held its November meeting in Springfield, Mass., on the 24th of the month. The members were the guests of the Westinghouse Electric & Mfg. Co. during the afternoon, visiting the Springfield plant of this company and viewing the methods of manufacturing automobile starting and lighting systems. The factory visit was followed by a meeting and dinner at the Hotel Kimball in the evening.

Automotive electrical service was the topic of a paper presented at the meeting by M. B. Speer, superintendent of the service department, Westinghouse Electric & Mfg. Co. He stated that many electrical service-stations are failing to impress each new customer with their ability and that automotive electrical service is a highly specialized branch of the automotive industry which cannot render service promiscuously. Most electrical service-stations make no attempt to analyze the average cost of a particular operation to determine whether that cost could be reduced by eliminating waste time and using special tools or equipment. A majority of stations accept a certain amount of idle time as a necessary evil and 40 to 50 per cent of the electrical repairman's time is unproductive for this reason. Mr. Speer cited his personal experience in managing and operating an electrical service-station to prove that idle time can be almost entirely eliminated by a simple method of time-keeping, a definite knowledge of the time required on each repair operation and by rendering service descriminately but impartially. Electrical service-stations have not paused often enough to ask themselves what constitutes a reliable service-station; cost and accounting systems have been neglected; shop and small-tool equipment has been inadequate; little has been done to increase trade. Immediate service is of no advantage if the service rendered is inefficient and results in a comeback.

The use of armatures rewound by specialty rewinding companies has proved unprofitable for many service-stations, according to Mr. Speer's experience. This is due to the unsatisfactory service such armatures have given. A recent investigation showed that 81 out of the 87 stations consulted, used rewound armatures in their service work. The average charge made to the customer is estimated at 75 per cent of that of a new armature, showing that the ultimate user pays dearly for a repaired piece of apparatus when a new armature would be a better and safer investment.

The New England Section meets in Boston, Dec. 22, at the Engineers Club when a paper on mechanical service will be read by Knox Brown of the Packard Boston service-station.

Washington Section

W. S. James, of the Bureau of Standards staff, has been appointed chairman of the committee that will be responsible for future meetings of the Washington Section. Mr. James is fortunate in having a number of automotive engineering authorities and scientists associated with him at the Bureau of Standards and this assures the presentation of many valuable papers before the Washington Section. The next meeting of the Section will be held at the Cosmos Club, Friday, Dec. 8.

Buffalo Section

Air-cooled automotive engines were the center of interest at the Buffalo Section meeting on Nov. 17 when C. P. Grimes, of the H. H. Franklin Mfg. Co., presented a very valuable paper. The meeting was most enthusiastic and the attendance exceeded 100 persons. Mr. Grimes outlined the major advantages of air-cooling as applied to passenger-car engines. He presented many data on performance, weight and efficiency, stating that air-cooling enabled the Franklin engineers to produce an engine weighing only 158 lb. with complete cooling equipment as compared with 213 lb. for a water-cooled engine of similar power characteristics. It was explained that Franklin economy of operation is dependent on the air-cooling principle to a large extent, not only because of the reduced weight but also because the engine operates at temperatures conducive to efficient fuel combustion. The fuel-consumption at 20 m.p.h. averaged 1.8 lb. per hp-hr. which compares with from 2.0 to 3.5 lb. per hp-hr. in other cars. At higher speeds the consumption drops to 0.7 lb. per. hp-hr. The author argued against providing powerplants in passenger cars that are capable of propelling the vehicle at speeds in excess of 50 m.p.h. when the average owner seldom exceeds 35 m.p.h. in his daily driving. Over-powering results in low fuel economy because of excessive weight throughout the entire chassis and because the engine is operated under a nearly closed throttle most of the time. Questions of blower design, piston fits, cylinder temperature, and blower noise were treated in the discussion following the paper.

The Buffalo Section has scheduled its next meeting on Dec. 15 at the Buffalo Engineers Club. Prof. G. B. Upton,

of Cornell University, will read what is expected to be a very instructive paper on Results of Testing Materials and Their Effects on Present-Day Engineering.

Dayton Section

The Dayton Section did not meet in November but has arranged what promises to be a very valuable session on Dec. 19 when P. S. Tice of the Stewart-Warner corporation will read a paper on the Utilization of Low-Grade Fuels in Automotive Engines. Dayton Section meetings are held at the Dayton Engineers Club and start at 8 o'clock. They are preceded by an informal get-together dinner at 6.30 p.m.

Pennsylvania Section

The design of passenger-car chassis springs received the attention of the Pennsylvania Section at its meeting, Nov. 24. H. B. Winchell, of William & Harvey Rowland, Inc., read the paper of the evening. He discussed spring action and flexibility, the effect of the Hotchkiss drive on riding-quality, natural periods of synchronism and methods of predicting probable spring action on completed vehicles. The paper includes passages on the effects of length, width, number and thickness of leaves, rebound leaves, rolled and diamond points and other details of spring construction. The various types of suspension were compared and their relative merits shown. Mr. Winchell strongly emphasized that it is better to give proper study to spring length, width and characteristics in the early stages of design than to find when the vehicle is completed that it is impossible to install proper type of springs in the space that has been provided for them by the designer.

The next meeting of the Pennsylvania Section will feature aeronautics and the principal speaker will be Com. R. D. Weyerbacher, U. S. N., who is stationed at Lakehurst, N. J. The meeting will be held, Dec. 28 at the Philadelphia Engineers Club, starting at 8 o'clock and will be preceded by the customary informal dinner at 6.30 p.m.

Indiana Section

The Indiana Section meeting on Nov. 9 was addressed by Fred E. Moskovics, vice-president of the Nordyke & Marmon Co., on the relation of the engineer to the sales and service branches of the industry. He divided motor-car engineering into two phases, theoretical or technical engineering and empirical or practical engineering. He felt it the duty of the service engineer to digest the troubles of the automobile operator so that they might be presented to the designing engineer as the basis of his empirical engineering work. The service department should function as the eyes and ears of the engineer in the operating field. Chief executives should organize channels for the assured consideration of the serviceman's suggestions, experience and complaints. The discussion of Mr. Moskovic's paper was very spirited and included remarks by Lon R. Smith, O. C. Berry, Fred Duesenberg, A. L. Nelson, David Landau and others.

J. H. Hunt, head of the electrical division of the General Motors Research Corporation, will address the next meeting of the Indiana Section on Dec. 14. His topic will be What Engineering Owes to Pure Science.

D. C. Teetor has been appointed treasurer of the Indiana Section to succeed Mark Smith who resigned because of his departure from Indianapolis.

Midwest Section

Dr. H. I. Schlesinger, professor of Chemistry at the University of Chicago, addressed the Midwest Section on the occasion of its meeting, Nov. 24. He explained the function of a catalyst in chemical reactions and stated the chemist's theory of catalytic action so that the automotive engineer could appreciate better the important part this scientific discovery has played in the refining and combustion of petroleum products.

The next meeting of the Midwest Section will be held in Milwaukee at the Milwaukee Athletic Club on Dec. 20. H. L. Horning will present the principal paper.

HIGH TEMPERATURE CAUSES EXCESSIVE VALVE-SEAT WEAR

THE Bureau of Standards was requested recently to investigate the cause of excessive valve-seat wear shown in a certain make of engine. These valve-seats were in some instances sunk into the cylinder block to a depth of nearly ¼ in. In every case the trouble was found in connection with the exhaust-valve seat, but it only occurred in a small number of engines of a given type, and even in the same engine all the exhaust-valve seats were not equally affected.

The cast iron of which the cylinder blocks were constructed was first examined, but this proved to be typical of the material usually employed in cylinder construction, and no difference was noted between the metal of the valve-seats showing excessive wear and those showing a normal amount. Next it was thought that difficulty might have been encountered in regrinding the valves, some of the valves not being affected by the grinding compound. This would result in the seat being ground away in a vain attempt to get satisfactory tightness. A few experiments were sufficient to eliminate this as a cause of the trouble.

Attention was next directed to conditions of operation that might account for the trouble. To determine the effect of cam outline and spring pressure, a cam that would give the valve about twice its normal lift and permit it to close very rapidly, thus striking the valve seat with considerable force was designed; but operation with this arrangement failed to show an abnormal rate of wear. However, with the valve and the seat heated to a dull red color, conditions were changed and the rate of wear was amply rapid to explain the trouble.

It should be mentioned in this connection that a reducing flame was used in these experiments to avoid any possibility of rapid wear through the oxidation of the metal. The temperatures reached in this experiment might result in actual operation from preignition or a very slow burning mixture, and it is probable that one of these conditions coupled with inadequate cooling of the valve-seats was responsible for the abnormal wear of the valve-seats in the engines under investigation.

Publications of Interest *to* S. A. E. Members

In this column are given brief items regarding technical books and publications on automotive subjects. As a general rule, no attempt is made to give an exhaustive review of the books, the purpose of this section of THE JOURNAL being rather to indicate from time to time what literature relating to the automotive industry has been published with a short statement of the contents.

SYMPOSIUM ON IMPACT TESTING OF MATERIALS. Collection of papers presented at the 25th annual meeting of the American Society for Testing Materials, 1315 Spruce Street, Philadelphia. 107 pp.; 27 illustrations.

This symposium, some of which may be of interest to automotive engineers, begins with a review of Impact Testing of Materials by H. L. Whittemore of the Bureau of Standards, in which the author gives a brief review of the subject, with a selected bibliography. This is followed by a series of three papers by D. J. McAdam, Jr., Thomas R. C. Wilson and Earl B. Smith, on machines and test specimens used in impact tests of metals, wood and road materials respectively.

Then follow two papers by C. L. Warwick and T. D. Lynch on American and British practice respectively, in Notched-Bar Impact-Tests of Metals. Finally, there are three interesting papers on Measurement of Impact by C. E. Margrum, Armin Elmendorf and H. F. Moore, and a paper on the Significance of Impact Tests by F. C. Langenberg and N. Richardson. The four last-mentioned papers in particular contain a critical discussion of some of the accepted methods of measuring impact pressures, and the significance of the results obtained with them, which should be of interest to engineers who are particularly concerned with the behavior of structural materials under conditions of impact, or under rapidly changing load.—H. C. D.

AIRCRAFT SPEED INSTRUMENTS. By Franklin L. Hunt and H. O. Stearns. National Advisory Committee for Aeronautics Report No. 127. Published by the National Advisory Committee for Aeronautics, City of Washington. 38 pp.; illustrated.

This report consists of three parts relating respectively to air-speed indicators, the testing of air-speed indicators and the principles of ground-speed measurement. Part 1 first discusses the different types of instruments that have been proposed for the measurement of air-speed and then gives detailed descriptions of most of the instruments that are used extensively and results of tests. A short discussion of the altitude effect on air-speed indicators is given with a practical table of corrections. Part 2 describes the methods of testing air-speed indicators used at the Bureau of Standards. Part 3 discusses the physical principles of ground-speed measurement and the methods that have been devised for their practical application to the determination of the ground speed of aircraft.

AERONAUTIC DIRECTION INSTRUMENTS, National Advisory Committee for Aeronautics Report No. 128. Published by the National Advisory Committee for Aeronautics, City of Washington.

This report, which is divided into four parts, covers the general field of direction instruments for aircraft. The adequacy of a consideration of the steady state of gyroscopic motion as a basis for a discussion of the displacements of a gyroscope mounted on an airplane is pointed out in the first part. The simple theory of the design of gyroscopic inclinometers and stabilizers is developed on this basis. The principal types of instruments are briefly described and their performance requirements stated. In the second part the testing and use of magnetic compasses for airplanes is dealt with briefly, while Part III contains a general treatment of the important features of the construction of aircraft compasses. Descriptions of the principal types used in America and in foreign countries are included. A brief history of the development of airplane turn indicators with detailed descriptions of all known types and makes is presented in the last section of the report. The results of laboratory and flight tests for the several available gyroscopic turn indicators are appended.

AUTOMOBILE CALCULATIONS. By James Watt. Paper read before the Institution of Automobile Engineers, 28 Victoria Street, Westminster, S. W., London, England. 72 pp.

The aim of the paper is primarily to aid draftsmen and designers, in bringing together in a convenient form calculation methods used in everyday design. The treatment is in the algebraic form and is applicable to light and heavy vehicle design. The calculations are grouped in four classes; the absolute, the comparative, the empirical and the approximate. The care used to distinguish between the types of formulas is very commendable for on the outset it helps the designer to gage the work according to the class of formulas that is being used.

The units of the vehicle treated in the paper are the engine, gearbox, clutch, universal-joints, rear axle, front axle and steering gear, springs, hand and foot brakes, frame and frame mountings, gear-ratio, road performances, special vehicles and accessories, weight of vehicle and the chassis as a unit and its component parts. The units are treated in full only so far as the author deems it to be advisable on the ground that many essential calculations are comparatively simple from a mathematical standpoint and such calculations have been omitted.

The paper is carefully prepared, clearly indicating its limitations as well as setting forth clearly its useful application. The author is to be complimented on his broadminded way in condensing so large a subject as automobile calculations into a paper of comparatively few pages.—A. L. N.

MATERIALS OF ENGINEERING. By Herbert F. Moore, includes a chapter on concrete by Harrison F. Gonnerman. Published by the McGraw-Hill Book Co., New York City. 305 pp.; 110 illustrations.

The author's preface states that the object of this textbook is to furnish a concise presentation of the physical properties of the common materials used in structures and machines, together with a brief description of their manufacture and fabrication. The book is intended primarily for use in technical schools, but may also prove useful to draftsmen, inspectors, machinists, and others, who, dealing with the materials of engineering in their daily work, wish to become familiar in an elementary way with the properties of those materials.

The author discusses the physical properties of materials and their ability to withstand deformation and to resist forces. He outlines the various methods used for testing materials to assure that service requirements will be met and describes concisely the methods of manufacture and fabrication into structures and machines of the different materials in common use.

While the text is elementary in character, for the reader who wishes to pursue his studies further there is given at the end of each chapter a list of selected references.

PNEUMATIC TIRES: AUTOMOBILE, TRUCK, AIRPLANE, MOTORCYCLE, BICYCLE. By Henry C. Pearson. Published by the India Rubber Publishing Co., New York City. 1323 pp.; numerous illustrations.

This book is described in the subtitle as "an encyclopedia of tire manufacture, history, processes, machinery, modern repair and rebuilding, patents, etc., etc., profusely illustrated." The author, a practical rubber-man, has made rubber tires and studied the subject in the leading tire factories of the United States and Europe. As publisher and editor

of the *India Rubber World* he is in a position to secure a large amount of material not accessible to others. The book may be accepted, therefore, as an authoritative treatment of the manufacture of the air-filled tire.

DURALUMIN: A DIGEST OF INFORMATION. By Horace C. Knerr. Paper presented at the Detroit Convention of the American Society for Steel Treating. 29 pp.; 18 illustrations.

Forged and heat-treated-aluminum alloys such as duralumin have been in use for a number of years, and it is not entirely clear why their use has been confined almost entirely to aircraft, in view of their apparent advantages in the automotive field. Aside from price, one of the factors that has limited their general use seems to have been a certain amount of distrust of these materials when produced in quantity for structural purposes.

H. C. Knerr, author of the paper reviewed here, is metallurgist of the Naval Aircraft Factory in Philadelphia. His paper should be of special interest to the automotive engineer, since it gives what appears to be an unbiased discussion of what duralumin is and what may be expected of it.

The history, composition and manufacture of this alloy are covered briefly. Its mechanical properties are discussed at some length and compared with steel for various purposes. There is a chapter on the fabrication of structural parts from duralumin stock and another on corrosion. The latter is treated at considerable length.

The last part of the paper is devoted to the constitution, metallography and theory of heat-treatment. This is of particular interest as it comprises a review of some of the work of several prominent metallurgists, accompanied by a discussion by the author. This is followed by a bibliography of the subject.

EXPERIMENTAL RESEARCH ON AIR PROPELLERS. By W. F. Durand and E. P. Lesley. National Advisory Committee for Aeronautics Report No. 141. 82 pp.; 51 illustrations; 8 plates. Published by the National Advisory Committee for Aeronautics, City of Washington.

This report will be of interest to those who are interested in air propellers. The previous reports of this series, Nos. 14, 30 and 64, have described in detail various findings of an important research project which has been in progress for a number of years at the Leland Stanford, Jr., University under Professor Durand. The present report is a review of the entire series of results of the preceding reports and includes a more complete analysis, graphical and otherwise, of these results. In making this review, any points that were considered doubtful from the results obtained in the first test have been checked by several repetitions of the tests.

The addition of a series of nomographic diagrams expresses the results of this important research in convenient form for use in determining the relative performance characteristics of a very wide variety of propeller designs selected so as to represent a continuous series, rather than distinct and independent types. We believe this report constitutes an important addition to the literature of this difficult subject.

OBITUARY

JOHN B. FOOTE, president and founder of Foote Bros. Gear & Machine Co., Chicago, died Oct. 12, 1922, aged 57 years. He was born at Chicago, April 6, 1865, received a public-school education and supplemented this with night lessons in drawing and in mathematics. He served an apprenticeship as a machinist for 4 years, followed this with practical work at die making and special machinery and, for a number of years, designed automatic machinery for can-manufacturing plants. For the last 29 years he was engaged in the production of automobile and tractor gears and tractor transmissions, having been a pioneer in the making of cut-steel, case-hardened, tough-cored gears for heavy-duty work. He was a charter member of the Society of Tractor Engineers. He was elected to Member grade in the Society of Automotive Engineers when the former organization was absorbed in 1917.

WILLIAM H. LITTLE, active in the automotive industry until his health failed in 1920, died at his home in Detroit, Oct. 26, 1922, aged 46 years. He was born at Westboro, Mass., Feb. 4, 1876. After his preliminary education, his early activities included 5 years of service as chief inspector and general foreman for the Locomobile Co., Bridgeport, Conn.; 1 year as superintendent for the Edison Storage Battery Co.; and 1½ years as manager of the New York City branch office of the Waltham Mfg. Co., Waltham, Mass.

In 1906 he became factory manager for the Buick Motor Co., Flint, Mich. Several years later he organized the Little Motor Car Co. that produced the "Little Car, made by Big Bill Little," as it was known to the trade. With the absorption of this enterprise by the Chevrolet Motor Co., Detroit, Mr. Little became its president. Later, he was general manager of the Sterling engine plant that built Chevrolet engines. Still later, he was made vice-president and managing director of the Scripps-Booth Corporation, Detroit.

Mr. Little was unmarried and is survived by his mother and one sister. He was elected to Member grade in the Society in 1908.

Applicants *for* Membership

The applications for membership received between Oct. 16 and Nov. 15, 1922, are given below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANDERSON, GEORGE POTTER, engineer, Graham Bros., *Detroit.*

AUSTIN, SAMUEL, service manager, Austin Auto Co., *Hartford, Conn.*

BAGGS, HOKE S., president, Norfleet-Baggs, Inc., *Salem, N. C.*

BEAL, S. H., assistant general manager, Jones & Lamson Machine Co., *Springfield, Vt.*

BLACKINTON, GEORGE WILSEY, works manager, Continental Motors Corporation, *Detroit.*

BLAUMAN, LOUIS W., sales engineer, Litho Etching Corporation, *Newark, N. J.*

BOWERS, GEORGE F., student, Purdue University, *Lafayette, Ind.*

BRADER, NORWOOD HAROLD, student, Cornell University, *Ithaca, N. Y.*

BROWN, JAY R., chief engineer, Western Automatic Machine Screw Co., *Elyria, Ohio.*

BROWNE, THEODORE C., vice-president, Brush Laboratories Co., *Cleveland.*

BULLARD, D. B., general mechanical engineer, Bullard Machine Tool Co., *Bridgeport, Conn.*

BULLARD, E. P., JR., president, Bullard Machine Tool Co., *Bridgeport, Conn.*

BULLARD, S. H., vice-president, Bullard Machine Tool Co., *Bridgeport, Conn.*

BURCH, LOUIS D., student, Purdue University, *Lafayette, Ind.*

BUSSARD, ROBERT MCCLELLAND, student, Purdue University, *Lafayette, Ind.*

CARMIN, KENNETH ARNOLD, student, Purdue University, *Lafayette, Ind.*

CORONADO, CHARLES A., student, Ohio State University, *Columbus, Ohio.*

COX, JOHN FITZHEW, student, Georgia School of Technology, *Atlanta, Ga.*

CROS, RENÉ L., student, Ohio State University, *Columbus, Ohio.*

DACOSTA, JOHN C., 3RD, mechanical engineeer, Baldwin Locomotive Works, *Philadelphia.*

DAVIS, LEWIS HENRY, student, Purdue University, *Lafayette, Ind.*

DORAN, JOSEPH F., production engineer, Crown Cork & Seal Co., *Baltimore.*

DYMENT, ALBERT ELLIOTT, sales engineer, Goulds Mfg. Co., *Seneca Falls, N. Y.*

ELLIS, J. H., service manager, Olds Motor Works, *Detroit.*

FEARNSIDE, RALPH STAFFORD, student, Purdue University, *Lafayette, Ind.*

FENN, GEORGE PRENTICE, student, University of Illinois, *Urbana, Ill.*

FREDERICK, CHARLES WALTER, student, University of Michigan, *Ann Arbor, Mich.*

GEBHARDT, C. W., vice-president and engineer, J. J. Schnerr Co., Inc., *San Francisco.*

GLOSSBRENNER, EDGAR L., student, Purdue University, *Lafayette, Ind.*

GODBOLD, E. J., engineer, Climax Engineering Co., *Clinton, Iowa.*

GOODFRIEND, IRVING FREDERICK, student, Columbia University, *New York City.*

GRAY, OTIS K., foreman, Remy Electric Co., *Anderson, Ind.*

GROSS, CLETUS, service manager, Welbon Dayton Motor Car Co., *Dayton, Ohio.*

GROSSER, NELSON O., service engineer, B. Robinson Supplies, Ltd., *Moose Jaw, Saskatchewan, Canada.*

GULF REFINING CO., *Pittsburgh.*

HANNUM, G. H., president and general manager, Oakland Motor Car Co., *Pontiac, Mich.*

HARWELL, ERNEST WILLIE, student, Georgia School of Technology, *Atlanta, Ga.*

HENRY, JAMES S., student, Georgia School of Technology, *Atlanta, Ga.*

HERBRAND CO., *Fremont, Ohio.*

HIGGINS, JAMES J., parachute engineer, Air Service, McCook Field, *Dayton, Ohio.*

HILGEDICK, RALPH V., technician, Stockland Road Machinery Co., *Minneapolis.*

HISCOX, DAVID C., student, Georgia School of Technology, *Atlanta, Ga.*

HOFFMAN, ROBERT G., engineer, Rochester Motors Corporation, *New York City.*

HOLWERDA, HARLEY C., student, Purdue University, *Lafayette, Ind.*

HORI, HISASHI, chief engineer, Yanese Automobile Co., *Tokyo, Japan.*

HUSING, HENRY A., draftsman, Holt Mfg. Co., *Stockton, Cal.*

INGALLS, H. D., assistant superintendent, Air Mail Field, *Cheyenne, Wyo.*

ISDAHL, EINAR, student, University of Wisconsin, *Madison, Wis.*

JOHNSON, PHILIP B., student, Ohio State University, *Columbus, Ohio.*

KELLOGG, H. DUDLEY, JR., student, Yale University, *New Haven, Conn.*

KINSEY, KENNETH HARRY, student, Purdue University, *Lafayette, Ind.*

KLOVER, PETER A., instructor airplane mechanics, United States Civil Service, *Rantoul, Ill.*

KNOWLTON, DALLAS, student, Purdue University, *Lafayette, Ind.*

LAKE, ENSIGN BURTON G., U. S. S. Wright, care Postmaster, *New York City.*

LANDES, JAMES U., engineer, Standard Oil Co., *Portland, Ore.*

LATIMORE, D. S., student, Alabama Polytechnic Institute, *Auburn, Ala.*

LEHMAN, MILTON S., student, Ohio State University, *Columbus, Ohio.*

LOCKWOOD, RALPH G., patent lawyer, Lockwood & Lockwood, *Indianapolis.*

MAEKAWA, EIICHI, electrical engineer, *Tokyo, Japan.*

MAGRAW, GEORGE F., draftsman, Packard Motor Car Co., *Detroit.*

MATSUMOTO, AKIYOSHI, engineer, Dodge Bros., *Detroit.*

MILLER, GEORGE LEE, vice-president and works manager, Gilliam Mfg. Co., *Canton, Ohio.*

MILLS, HARVEY FRETZ, student, Purdue University, *Lafayette, Ind.*

MOE, ORION G., student, Leland Stanford, Jr., University, *Stanford University, Cal.*

NAKASHIMA, CAPT. TOTARO, Motor Transport Corps, Imperial Japanese Army, *Setagaya, near Tokyo, Japan.*

NUTT, FORREST H., student, Purdue University, *Lafayette, Ind.*

PACKARD, JOSEPH A., student, University of Michigan, *Ann Arbor, Mich.*

PATTERSON, JACK WATKINS, student, Georgia School of Technology, *Atlanta, Ga.*

PECK, NELSON CHAFFEE, student, Yale University, *New Haven, Conn.*

PERKINS, ERNEST DELLA, student, University of Michigan, *Ann Arbor, Mich.*

PETERS, JENNINGS D., student, University of Washington, *Seattle, Wash.*

PHILLIPS, WILLIAM RUSSELL, JR., student, Georgia School of Technology, *Atlanta, Ga.*

PLACE, REUBEN MEREDITH, branch manager, Ahlberg Bearing Co., *Toledo.*

REYBURN, JOHN R., engineer, American Chain Co., *Bridgeport, Conn.*

RHAME, P. W., instructor, University of Minnesota, *Minneapolis.*

RIGGS, HAROLD T., student, Purdue University, *Lafayette, Ind.*

ROSS, WALTER DAVID, student, Purdue University, *Lafayette, Ind.*

ROSSIN, MAURICE S., student, Purdue University, *Lafayette, Ind.*

ROTH, GEORGE F., factory manager, Anchor Top & Body Co., *Cincinnati.*

RUFF, EDWARD ALBERT, student, Ohio State University, *Columbus, Ohio.*

SCHADT, E. K., electric engineer, Cadillac Motor Car Co'., *Detroit.*

SCHNERR, J. J., manufacturer of gears and automobile parts, J. J. Schnerr Co., Inc., *San Francisco.*

SCHWIZER, PAUL EUGENE, student, Polytechnic Institute of Brooklyn, *Brooklyn, N. Y.*

SENDELBACH, EDWARD C., manager of wheel department, Hopkins Mfg. Co., *Hanover, Pa.*

SHELLER, GEORGE A., service manager, William Parkinson Motor Sales Co., *New York City.*

SHICK, WILLIAM KENNETH, student, Purdue University, *Lafayette, Ind.*

SIMPSON, E. L., president and engineer, E. L. Simpson, Ltd., *Montreal, Que., Canada.*

SLOCOMBE, W. VERNON, assistant engineer in charge of production, Turbulator Corporation, *Chicago.*

SOLT, VIVIAN M., builder of racing cars and student, Solt Motors, *Manhattan, Kan.*

SPRING, FRANK S., chief engineer, Courier Motors Co., *Sandusky, Ohio.*

STENBERG, THORNTON R., sales representative, Walden-Worcester, Inc., *Worcester, Mass.*

STEVENSON, ROSS J., student, University of Illinois, *Urbana, Ill.*

STRAIN, CLIFFORD, student, Stevens Institute of Technology, *Hoboken, N. J.*

SWANSON, RAYMOND E., student, Purdue University, *Lafayette, Ind.*

TAYLOR, J. H., student, Purdue University, *Lafayette, Ind.*

TAYLOR, ROBERT HUGH, assistant chief engineer, Universal Boiler Co., *Denver, Col.*

TERMAN, MARK J., student, Purdue University, *Lafayette, Ind.*

TEXTILEATHER CO., *New York City.*

THOMAS, THEODORE P., student, Purdue University, *Lafayette, Ind.*

THOMPSON, GORDON B., student, Purdue University, *Lafayette, Ind.*

TODD, FILLMORE W., president, Accessories Mfg. Co., *Chicago.*

VIDALIE, RENÉ M., designer-engineer, Doble Steam Motors, *San Francisco.*

WALLACE, BERNARD W., student, Purdue University, *Lafayette, Ind.*

WIEBERG, T. C., student, Purdue University, *Lafayette, Ind.*

WILCOX, FRED A., engineer, Advance-Rumely Co., *La Porte, Ind.*

WILKINSON, JAMES MCCLELLAN, student, Georgia School of Technology, *Atlanta, Ga.*

WILLIAMS, EMERSON MARION, student, University of Michigan, *Ann Arbor, Mich.*

WOLEVER, WALTER BRIAN, student, Purdue University, *Lafayette, Ind.*

WORMLEY, HAROLD W., assistant carbureter engineer, Cadillac Motor Car Co., *Detroit.*

Applicants *Qualified*

The following applicants have qualified for admission to the Society between Oct. 10 and Nov. 10, 1922. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff) Affiliate; (S M) Service Member; (F M) Foreign Member; (E S) Enrolled Student.

ANTHONY, JOHN EDWARD (M) designing engineer, tractor works, International Harvester Co., *Chicago,* (mail) 4112 West Jackson Boulevard.

BEAN, WILLIAM LLOYD (M) mechanical assistant to president, New York, New Haven & Hartford Railroad, *New Haven, Conn.*

BREWSTER, WILLIAM (M) president, Brewster & Co., Bridge Plaza, *Long Island City, N. Y.*

BROWN, JOHN W. (A) general manager, John W. Brown Mfg. Co., *Columbus, Ohio.*

BUTCHER, HAROLD E. (A) sales manager, Champion Spark Plug Co., *Toledo.*

BUTTRICK, W. B. (A) chief mechanic and superintendent, Miller North Broad Storage Co., *Philadelphia,* (mail) 1521 Venango Street.

COLEY, GLENN (A) metallurgist, Timken-Detroit Axle Co., 136 Clark Avenue, *Detroit.*

HOLZ, FRED C. (A) service inspector, Gomery-Schwartz Motor Car Co., *Philadelphia,* (mail) 157 North 20th Street.

JACKSON, E. F. (A) manager of manufacturers sales, Goodyear Tire & Rubber Co., Inc., *Detroit,* (mail) 2817 East Grand Boulevard.

LUTZ, EARL C. (M) assistant superintendent, International Harvester Co., Chicago, (mail) 1913 South 49th Avenue, *Cicero, Ill.*

NATIONAL MALLEABLE CASTINGS CO. (Aff) 10,600 Quincy Avenue, *Cleveland.*
Representatives:
Bellman, W. B., sales agent, Toledo.
Hiatt, H. I., sales agent, Chicago.
Slater, James A., assistant manager of sales.
Wasson, S. C., sales agent, Indianapolis.

NEAL, JAMES BENSON (M) manager, Norton Laboratories, Inc., *Lockport, N. Y.*

NORWOOD, H. E. (M) general manager and engineer, Perfect Window Regulator Co., 20 Exchange Place, *New York City.*

SMITH, STANFORD ALLEN (M) chief inspector, Lexington Motor Co., *Connersville, Ind.*

STREETER, EDWARD L., JR. (A) general manager, J. N. LaPointe Co., *New London, Conn.,* (mail) 85 Squire Street.

TAKAO, SHIGEZO (F M) engineer, Takao Iron Works Co., Kobe, Japan, (mail) *Oishi near Kobe, Japan.*

THE JOURNAL OF THE SOCIETY OF AUTOMOTIVE ENGINEERS

INDEX TO VOLUME XI, JULY-DECEMBER, 1922

THE

JOURNAL
OF THE SOCIETY OF
AUTOMOTIVE ENGINEERS

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Issued monthly, $1 a number, $10 a year; foreign $12 a year; to members, 50 cents a number, $5 a year. Entered as second-class matter, Aug. 23, 1917, at the post office at New York, N. Y., under the Act of Aug. 24, 1912. Acceptance for mailing at special rate of postage provided for in Section 1103, Act of Oct. 3, 1917, authorized on Aug. 2, 1918.

B. B. BACHMAN, *President* COKER F. CLARKSON, *Secretary* C. B. WHITTELSEY, *Treasurer*

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INDEX

Personal Notes of the Members

Items regarding changes in business connections, promotions, etc., are desired from the membership for insertion in these columns. This will enable members to keep their friends informed of their whereabouts and will also assist in keeping the records of the Society up to date.

D. M. Ackerlind is no longer designer and layout man for the H. H. Franklin Mfg. Co., Syracuse, N. Y., but has become designer in the tank, tractor, trailer and artillery vehicle mount section of the Ordnance Department, Rock Island Arsenal, Ill.

Alfons A. Altenberg has been appointed chief engineer and production manager for the Falls Motors Corporation, Sheboygan Falls, Wis. He was formerly head of the engineering department of the Kohler Co., Kohler, Wis.

W. F. Anklam, secretary and general manager of the C. M. Hall Lamp Co., Detroit and Kenosha, Wis., was elected president of this company. He relinquishes the position of secretary, which he has held for the past 12 years, but will continue to act as general manager.

Carroll M. Aument has accepted a position as engineer with the International Motor Co., New York City.

Dickerson G. Baker, until recently practicing consulting engineering in Willimantic, Conn., is now mechanical engineer with the American Thread Co., Fall River, Mass.

Peter Barbeck has severed his connection with the F. V. F. Machine Works, New York City, where he was master mechanic, and has been made vice-president and general manager of the Aetna Auto Engineering Corporation, 217 West 64th Street, New York City.

J. B. Bartholomew, president of the Avery Co., Peoria, Ill., was elected president of the National Association of Farm Equipment Manufacturers at its recent annual meeting.

Ernest A. Bell has been made superintendent of the Canada Cycle & Motor Co. (Victoria), Proprietary Ltd., Melbourne, Victoria, Australia. He was formerly general manager and chief engineer of the Globe Motor & Taxi Co., also of Melbourne.

Charles J. Biddle has been appointed factory superintendent of the Sunset Mfg. Co., Berkeley, Cal. He previously attended the California Institute of Technology, Pasadena.

F. E. Booth has been promoted from assistant sales manager to sales manager of the motor bearings division of the Hyatt Roller Bearing Co., Detroit.

Bruce Borland has been appointed consulting engineer for the Chicago Car Seal Co., Chicago.

In connection with the reorganization of the American Metal Parts Corporation, Boston, Mass., as the American Metal Parts Co., **Joseph Bornstein** has been appointed vice-president, works manager and chief engineer. He was president, works manager and chief engineer of the American Metal Parts Corporation.

F. M. Boyd, who was formerly manager, secretary and treasurer of the Motor Parts Corporation, Baltimore, is now doing engineering work on his own account in that city.

Joseph W. Bramwell has made arrangements with the National Scale Corporation, Chicopee Falls, Mass., whereby he will represent it in Philadelphia.

(*Continued on p.* 4)

Personal Notes of the Members

Continued

John S. Burdick, formerly vice-president and general manager of the Buffalo Body Corporation, Buffalo, has been elected president and general manager of the Burdick-Atkinson Corporation, which has been incorporated to manufacture steel wire springs for automobile upholstery at Hamburg, N. Y.

Ralph B. Burton has accepted a position with the White Motor Co., Cleveland.

Ernest F. Carlson is engaged in testing work in the powerplant of the Minneapolis Street Railway Co., Minneapolis. He formerly attended the University of Minnesota.

Peter C. Christman has severed his connection with the Canadian General Electric Co., Toronto, Ont., Canada, and has been appointed sales engineer for the Brown Engineering Corporation, also of Toronto.

Charles W. Claassen has accepted a position as service manager for the Bauer Auto Sales Co., Cincinnati, Ohio.

R. W. Cory is now affiliated with the Western Electric Co., Chicago.

Stanley R. Cummings has been appointed instructor of mechanical engineering at Lafayette College, Easton, Pa. He was previously assistant professor of mechanical engineering at Oregon State Agricultural College, Corvallis, Ore.

S. J. DeFrance has become junior aeronautical engineer with the National Advisory Committee for Aeronautics, Langley Field, Hampton, Va. He formerly attended the University of Michigan, Ann Arbor, Mich.

Albert H. Deimel, until recently experimental engineer for the Chrobaltic Tool Co., Michigan City, Ind., has accepted a position as designer for the Buda Co., Harvey, Ill.

Eric H. Delling, who was formerly chief engineer of the Stanley Motor Carriage Co., Newton, Mass., has been made vice-president and chief engineer of the Delling Motors Co., Philadelphia.

Albert F. de Maringh has accepted a position as sales manager for the Thermo Vacuum Systems, Detroit. He was previously sales engineer for Marburg Bros., Inc., New York City.

Clifford H. Dengler, formerly head engine designer for the Fox Motor Car Co., Philadelphia, is now associate engineer with the Automotive Engineering Consultants, also of Philadelphia.

Robert M. de Vignier has accepted a position as engineer with the duPont Motors, Inc., Moores, Pa.

James J. Dimeo has been made production manager for the Dura Co., Toledo, Ohio. Until recently he was manager for Jaxon Co., also of Toledo.

Walter E. Dugan, formerly manager of the Cincinnati axle plant of the Standard Parts Co., Cleveland, has been elected vice-president and general manager of the Shuler Axle Co., Louisville, Ky.

Fay A. Dun, who was previously instructor in the Ohio State University, Columbus, is now engaged in doing production and design work for the Groeniger Mfg. Co., also of Columbus.

C. M. Eason has severed his connection with the Samson Tractor Co., Janesville, Wis., where he held the office of vice-president. He has not announced his plans for the future.

Robert D. Easton has become chief engineer for the Brandt Mfg. Co., Watertown, Mass. He was formerly designer and engineering draftsman for the General Tractors, Inc., Chicago.

Clyde L. Edwards has been made chief inspector for Canadian Products, Walkerville, Ont.

Lewis G. Fairbank, who previously was vice-president and manager of the Firestone Steel Products Co., Akron, Ohio, is now sales manager of the Firestone Tire & Rubber Co., also of Akron.

(*Continued on p. 6*)

PERSONAL NOTES OF THE MEMBERS

Continued

F. B. Farquharson has accepted a position as draftsman with the Kirsten Boeing Engineering Co., Seattle, Wash. He formerly attended the University of Washington, Seattle.

D. C. Fleming has been appointed district service and sales manager for the Phelps Light & Power Co., Rock Island, Ill. He was formerly superintendent of instruction in the automobile school maintained by the Young Men's Christian Association at Davenport, Iowa.

O. L. Formigle has resigned as chief engineer for the Wichita Motors Co., Wichita Falls, Texas. His plans for the future have not been announced as yet.

Charles P. Friedrich is attending the University of Pittsburgh, as a special student in the school of engineering. He was previously aeronautic draftsman and designer in the Naval Aircraft Factory, League Island Navy Yard, Philadelphia.

Otis C. Friend, who was formerly supervisor of sales for the R. L. Dollings Co., Columbus, Ohio, has become associated with the Paige & Jones Chemical Co., Chicago.

A. H. Frost has severed his connection with the Cox Brass Mfg. Co., Albany, N. Y., where he was sales engineer. His plans for the future have not been announced.

H. B. Garman has been elected president and general manager of the Garman Mfg. Co., Detroit.

H. H. Gildner has been appointed district manager of sales, with headquarters at Chicago, for the Timken Roller Bearing Co., Canton, Ohio.

R. J. Gilmore has become affiliated with B. J. Baker & Co., Boston. He was formerly president of Hare's Motors of New England, also at Boston.

Jacob E. Gramlich, who was previously chief engineer and factory manager for the Sanford Motor Truck Co., Syracuse, N. Y., has become chief engineer for the Watson Truck Corporation, Canastota, N. Y.

G. A. Green has resigned as vice-president and general manager of the Fifth Avenue Coach Co., New York City, to accept a similar office with the Chicago Motor Bus and American Motor Bus Mfg. companies, Chicago.

F. Walter Guibert has been appointed sales manager of the Detroit office of the Interstate Iron & Steel Co., Chicago. He formerly held a similar position in Detroit for the Massillon Rolling Mill Co., Massillon, Ohio.

Leon J. D. Healy is no longer technical manager of the Racine Auto Tire Co., Racine, but has been made secretary and treasurer of the Wright Rubber Products Co., also of Racine.

The offices of the Heckman Signal Co., of which **William E. Heckman** is secretary and engineer, have been removed from Denver, Col., to 117 Bowen Street, St. Louis.

Bradford B. Holmes has accepted a position as development engineer for the Brunswick Refrigerating Co., New Brunswick, N. J.

George H. Houston has been elected president of the General Sugar Co., Havana, Cuba.

J. A. Howlett has been made service manager for Gray-Dort Motor Sales, Chatham, Ont.

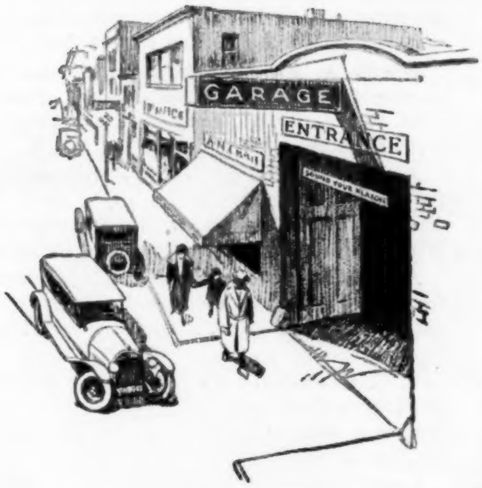
Henry M. Hubbard has been appointed supervisor of drafting for the White Motor Co., Cleveland.

Lindley D. Hubbell has severed his connection with the Hendee Mfg. Co., Springfield, Mass. No announcement has been made of his future plans.

Thomas Jackson, who was formerly draftsman for the Holt Mfg. Co., Peoria, Ill., has accepted a similar position with the Russell Motor Axle Co., Detroit.

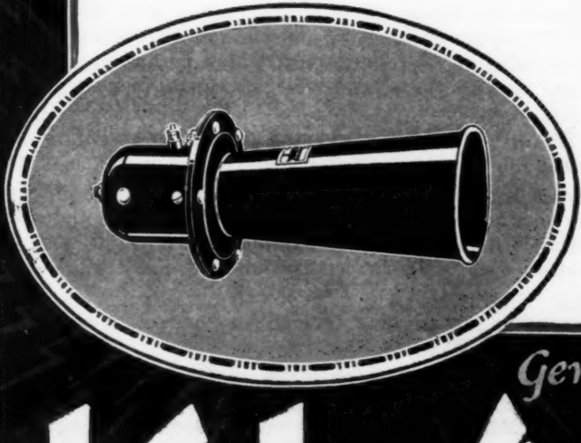
(*Continued on p. 8*)

ALWAYS BE CAREFUL



Look towards the street before crossing the entrance driveway of a garage or service station. A car may just be turning in from the street. A moment's caution will assure your safety

IT is incumbent on the motorist turning in from the street to warn pedestrians on the sidewalk. This is especially true if they are proceeding in the same direction as your car. Give them timely warning from your Klaxon. Klaxon is synonymous with safety for all.



Genuine Klaxon Horns made only by

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PERSONAL NOTES OF THE MEMBERS

Continued

Jesse M. Jenkins, having been graduated from Purdue University, Lafayette, Ind., is now inspector for the Western Electric Co., Chicago.

John Erik Jonsson, who took a course in mechanical engineering at Rensselaer Polytechnic Institute, Troy, N. Y., has accepted a position as mechanical engineer in the operating department of the United States Aluminum Co., Alcoa, Tenn.

Frank A. Kateley has become associated with the Automotive Corporation, Toledo, Ohio. Previously he was president and general manager of the Fremont Motors Corporation, Fremont, Ohio.

Andrew L. Kimball, who was formerly automobile salesman for the Thompson Auto Sales Co., Detroit, has been appointed district sales manager, with headquarters in that city, for the Wheeler-Schebler Carbureter Co., Indianapolis.

Adolph Klein has resigned his position as chief draftsman for the Fifth Avenue Coach Co., New York City, and has associated himself with the Klein Printing Co., also of New York City.

V. C. Kloepper, who was formerly designing engineer with the Dorris Motor Car Co., St. Louis, has severed his connection with that organization. He has not announced his plans for the future.

Louis T. Knocke has severed his connection with the Falls Motors Corporation, Sheboygan Falls, Wis., where he was chief engineer. His plans for the future have not been announced as yet.

Louie F. Koellner, who was until recently draftsman for the Fulton Iron Works, St. Louis, has accepted a similar position with the Traffic Motor Truck Corporation, also of St. Louis.

Charles W. Kramlich is now affiliated with the Fafnir Bearing Co., New Britain, Conn., as sales engineer covering Wisconsin and Minnesota. He was formerly assistant chief engineer with the U. S. Ball Bearing Mfg. Co., Chicago.

A. J. Langhammer has been appointed mechanical superintendent of the C. G. Spring & Bumper Co., Kalamazoo, Mich. He was formerly consulting engineer for Thompson & Worley, Detroit.

George L. Lavery has been appointed general manager of the Tire and Rim Association of America, Inc., and will in the future be located at the offices of the association, 537 Leader-News Building, Cleveland. He was formerly manager of the steel wheel department of the West Steel Casting Co., also of Cleveland, with which he has been associated for the past 10 years, and will continue to act as its consulting engineer.

William V. Lowe has accepted a position as engineer salesman for the Consumers Service Station's Consolidated, Boston.

James Lynah has been made assistant director in the purchase section as well as a member of the advisory staff of the General Motors Corporation, Detroit. He was formerly vice-president and treasurer of Barnard-Lynah, Inc., New York City.

George L. McCain has severed his connection with Colonial Motors, Ltd., Windsor, Ont.

W. J. McVicker has been made superintendent of the plant of the Minneapolis Threshing Machine Co., Minneapolis, at Hopkins, Minn. He was previously consulting engineer and general manager for the McVickers Engineering Co., also of Minneapolis.

F. H. Marmon has become associated with the Nordyke & Marmon Co., Indianapolis. He attended the Massachusetts Institute of Technology, Cambridge, Mass., until recently.

Robert H. Martin, who was formerly president of the Southeastern G. M. C. Truck Co., Atlanta, Ga., now holds a similar office in the Martin-Nash Motor Co., also in Atlanta.

(*Continued on p.* 10)

Personal Notes of the Members

Continued

Eugene L. Mench, Jr., has accepted a position as designing engineer for the Service Motor Truck Co., Wabash, Ind.

Clarence W. Miller, who was previously chief engineer of the A. Howard Co., Galion, Ohio, has become affiliated with Robert H. Hassler, Inc., Indianapolis.

Sherod S. Noe has become associated with the Aero Products Co., New York City, in the capacity of general manager and chief engineer. He was formerly chief engineer for the Tool & Auto Products Co., Cleveland.

W. T. Norton, Jr., has been appointed chief engineer of the L. M. Axle Co., Cleveland.

Arthur D. Osborne, who was until recently connected with the Apsco Service, New York City, has accepted a position with the Patterson-Andress Co., also of New York City.

John F. Palmer has become affiliated with the Hewitt Rubber Co., Buffalo, N. Y.

E. L. Peterson, who was formerly machine designer for the Western Electric Co., Chicago, is now tool designer for the Addressograph Co., also of that city.

E. M. Pfauser has accepted a position as designing engineer for the Valley Iron Works Co., Appleton, Wis. He was previously engineer in charge of design for the International Cultivator Corporation, Oshkosh, Wis.

Augustus G. Prosperi has been made vice-president and sales manager of the Oakland Sales Co., Tampa, Fla. His previous position was that of retail sales and service manager for the Oakland Motor Car Co., Atlanta, Ga.

Louis P. Prossen was recently elected president and treasurer of the Shaw Cab Motor Service, Inc., New York City. He was previously secretary and treasurer of the Orteig Motor Co., Inc., also of New York City.

Leon H. Reed, who was temporarily connected with the Salisbury Axle Co., Jamestown, N. Y., has accepted a position with the Kurtz Motor Car Co., Cleveland.

Cyril Rhodes has joined the engineering department in Plant No. 1 of the Studebaker Corporation of America, South Bend, Ind. He recently attended Cornell University, Ithaca, N. Y.

Earl C. Rieger has accepted a position as tool detailer in the tractor works of the International Harvester Co., Chicago. He formerly attended the Armour Institute of Technology in that city.

Walter C. Robbins, who until recently was general manager for the Eberhart Steel Products Co., Buffalo, N. Y., is now president and general manager of the W. C. R. Engineering Co., also of Buffalo.

Harry Rose has been engaged as Lincoln sales manager by the F. F. Wood Motor Co., Grand Rapids, Mich. He was previously business manager for the W. D. Block Motor Co., also of Grand Rapids.

R. S. Russell has joined the forces of the Barley Motor Car Co., Kalamazoo, Mich., and is doing designing in connection with new Barley six and taxicab projects.

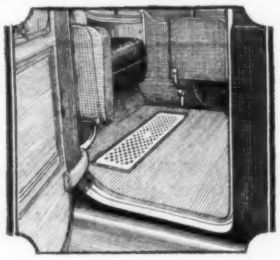
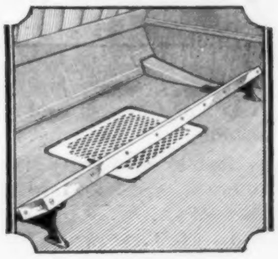
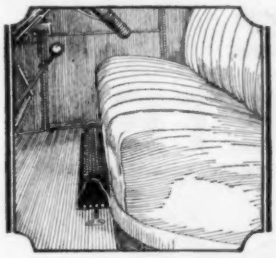
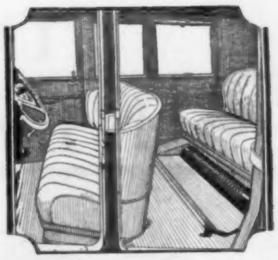
P. R. Sandieson, who was formerly engineer for the Pittsburgh Model Engine Co., Pittsburgh, has become associated with the Standard Steel Car Co., Butler, Pa.

F. J. Scarr, until recently assistant superintendent of motor vehicles for the Standard Oil Co. (N. J.), at Baltimore, has been appointed transportation engineer for the Motor Haulage Co., New York City.

Clifford J. Schlafman has accepted a position as tool designer and checker for the Federal Tool & Machine Co., Dayton, Ohio. He attended the Ohio State University, Columbus, prior to this.

F. A. Schumann has accepted a position as mechanical engineer for the Studebaker Corporation of America, South Bend, Ind.

(Concluded on p. 12)


PERFECTION HEATER
GB
2,347,266
CLEVELAND OHIO
THE PERFECTION HEATER & MFG. CO.

PERSONAL NOTES OF THE MEMBERS

Concluded

W. L. Scribner has become associated with the Coats Steam Car Co., Chicago, and is located at the sales office in Columbus, Ohio.

Ralph H. Sherry is engaged in consulting practice as a metallurgical and industrial engineer with headquarters at Elizabeth, N. J. Formerly he was metallurgical engineer with the General Motors Corporation and more recently with the Willys Corporation.

Lon R. Smith has resigned as vice-president in charge of sales and advertising of the Midwest Engine Co., Indianapolis. His plans for the future have not been announced as yet.

Mark A. Smith, who was formerly sales engineer of the Midwest Engine Co., Indianapolis, has become affiliated with the American Motor Truck Co., Newark, Ohio, in the capacity of executive of a new division known as the motorbus division.

P. W. Steinbeck has resigned as body engineer for the H. H. Babcock Co., Watertown, N. Y., to accept a position with the American Body Co., Buffalo, N. Y.

Charles E. Stoddard has severed his connection with the American Steam Truck Co., Chicago, where he was doing designing and laying out steam passenger cars. He has not announced his plans for the future.

Stuart J. Thomas has accepted the position of superintendent of the Crosley Mfg. Co., Cincinnati, Ohio.

G. K. Throckmorton has been made vice-president and treasurer of Herbert H. Frost, Inc., Chicago. He was formerly manager of the electric plant department of the Sears, Roebuck Co., also of Chicago.

Paul C. Tietz has accepted a position as die-casting engineer for the H. G. Saal Co., Chicago. He was previously tool designer for the Aermotor Co., also of Chicago.

Fred I. Tone has severed his connections with C. H. Wills & Co., Marysville, Mich., where he has been engineering executive during the development and production of the Wills Sainte Claire car. No announcement has been made of his future plans.

Ethan Viall has been appointed Ohio editor of the *American Machinist*, with headquarters at Cincinnati. This marks his return to the editorial staff of this publication with which he was connected for 11 years, being successively associate, Western, managing and consulting editor. In the early part of this year he severed his connection with that periodical to become general manager of T. W. Minton & Co., Barbourville, Ky.

W. R. Vohrer, who was formerly designer in the ordnance engineering laboratory of the Holt Mfg. Co., Peoria, Ill., has become chief draftsman for the Sterling Engine Co., Buffalo.

Fred W. Warner has become affiliated with the Durant Corporation, Pontiac, Mich. He was previously president and general manager of the Oakland Motor Car Co., also of Pontiac.

Glenn Weller has accepted a position with the Westinghouse Electric Products Co., Mansfield, Ohio. He was formerly designer for the Ohio Brass Co., also at Mansfield.

James W. Wilford is now affiliated with the Melling Forge Co., Lansing, Mich. Until recently he held the position of general manager with the Central Products Co., Detroit.

Rex C. Willis, who was formerly tractor engine mechanical expert for the Standard Oil Co. (California), San Francisco, has been made foreman in charge for Jones & Pitzer, Seattle, Wash.

George W. Winquist has joined the engineering department of the Panama Power & Light Co., Panama, Republic of Panama. He previously attended the Rensselaer Polytechnic Institute, Troy, N. Y.

J. A. Young, who until recently was vice-president and general manager of the Dunkirk Axle Corporation, Dunkirk, N. Y., is now sales manager for the Willys-Morrow Co., Elmira, N. Y.

ARMOR
BUSHINGS

American Bronze Corporation
presents an entirely new type of
BUSHING
Steel-Jacketed Bronze-Lined

After months of research, experimenting and testing, the makers of Non-Gran Bronze Bushings announce a new product—the "Armor Bushing,"—a steel shell with a hard bronze lining.

A way has been found to anchor a bronze lining in a steel jacket in such a way as to preclude any possibility of its working loose. This bronze lining is pressed into the steel jacket and locked in place by a novel process (patent applied for). This results in a unit bushing that combines the strength of steel with the bearing characteristics of bronze.

Armor Bushings eliminate completely the necessity of broaching or reaming after assembly. Once pressed into place, they are ready for service. Contraction of the bore of the Armor Bushing for a given press-fit is constant and can be definitely pre-determined.

TYPE OF BUSHING	Tensile Strength	Scleroscope Hardness	Relative contraction of inside diameter in pressing into place	Operations after assembly or replacement	Relative Pressure to press in	Relative Pressure to press out
Cast (Phosphor)	22,000-25,000	14-15	2	Broaching or Reaming	400-600 lbs.	500-600 lbs.
Rolled	54,000	28-32	Depending upon closeness of seam and other factors	Broaching or Reaming	Depending upon closeness of seam and other factors	Depending upon closeness of seam and other factors
ARMOR	Steel - - 70,000 Bronze - 54,000	Steel Jacket 32-34 Bronze Lining 28-32	1	None	1,400 lbs.	1,650 lbs.

This table shows the difference in the chief characteristics of Armor Bushings and other types of bronze bushings.

The comparisons show just what a real advance Armor Bushings represent. The idea is so simple that the thought occurs—"Why didn't someone think of that before?"

The bronze lining is distinctly hard and consequently wear-resisting. The scleroscope hardness (hard metals scale) is 28 to 32 as compared with 14 to 15 for common cast bronze.

Armor bushings are ideal for spring-eye and shackle duties. Instant approval and endorsement have been given by both spring makers and car manufacturers to which industry the initial production will be devoted.

Samples and complete engineering data on request.

American Bronze Corporation

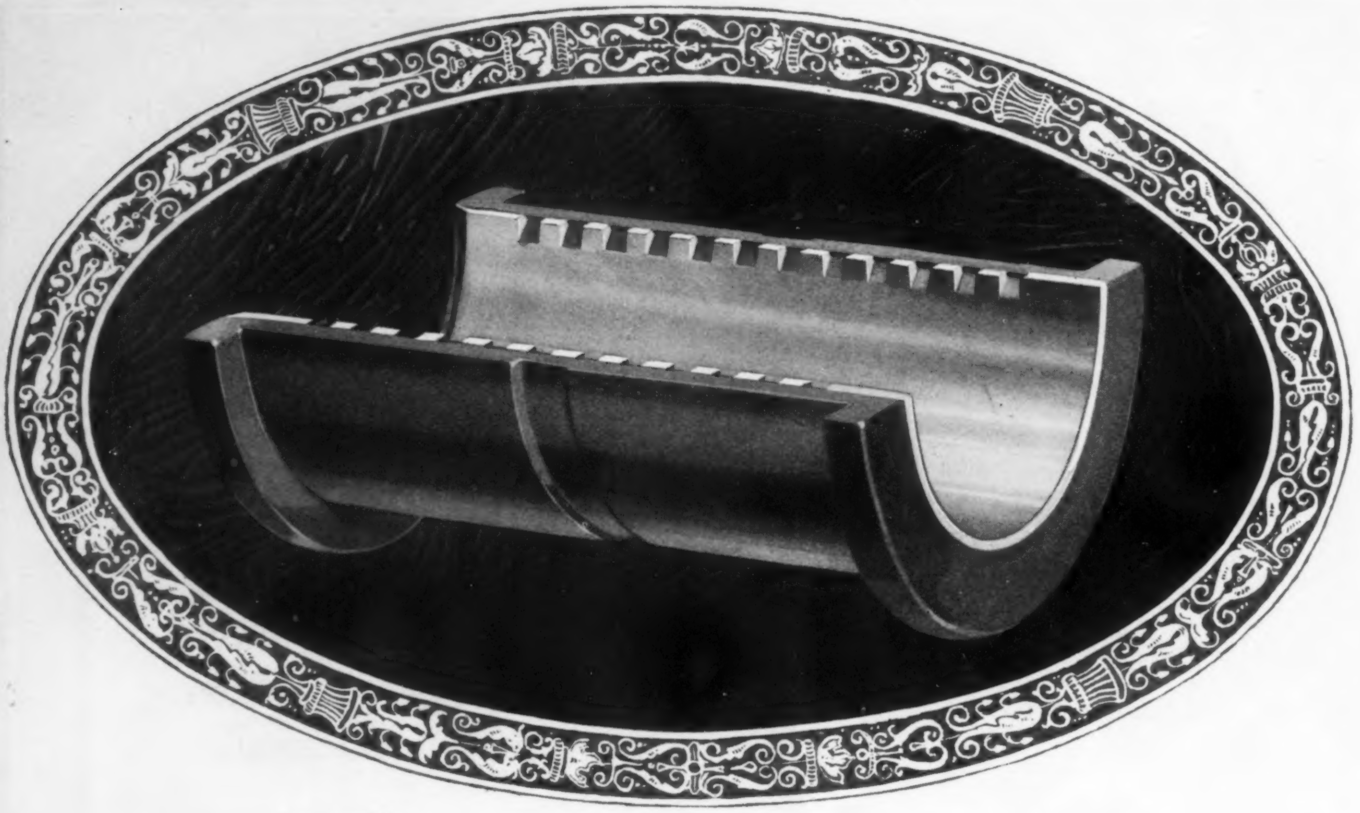
Berwyn, Penna.

ARMOR BUSHINGS


STOP
STOP
HOTEL


Strom


QUALITY
SNAP RINGS
"Cast to Last"
Easy to Install
Quick Seating
Long Lived
Accurate
DEPENDABILITY REPUTATION
AUTOMOTIVE EQUIPMENT ASSN
JUSTICE QUALITY
MORE than 60 leading manufacturers have adopted QUALITY piston rings for initial installation.
All Jobbers and Dealers should be able to visualize the enormous replacement market for QUALITY piston rings and keep well stocked.
More Than a Million a Month
QUALITY
QUALITY
SNAP RINGS
12-4 1/2 .015 X 5/16
THE Piston RING COMPANY
MUSKEGON, MICH.

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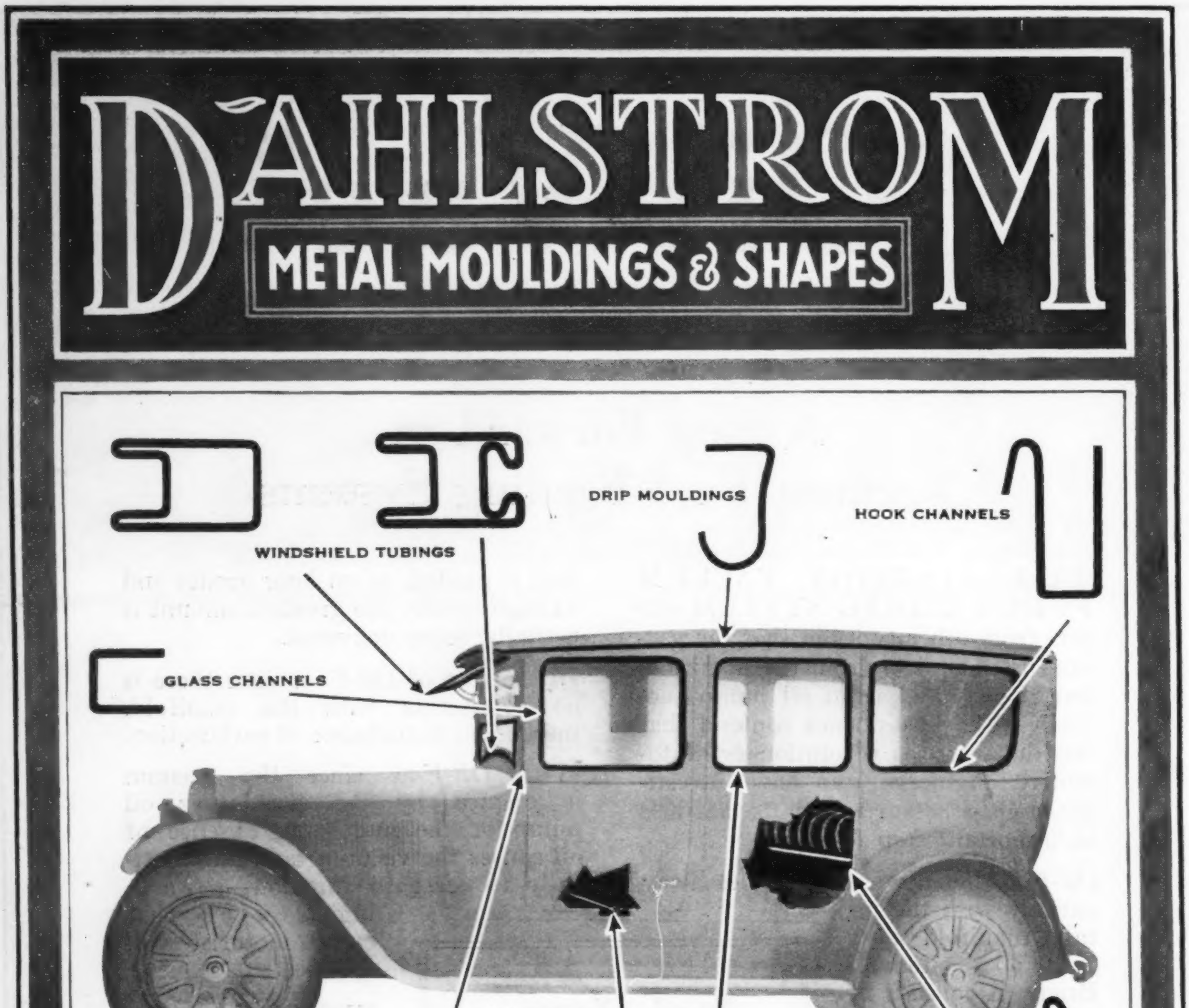
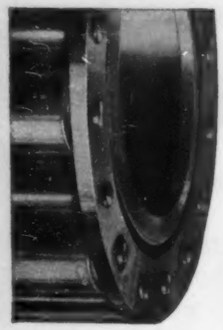
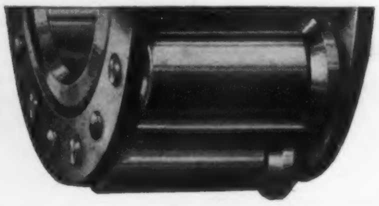
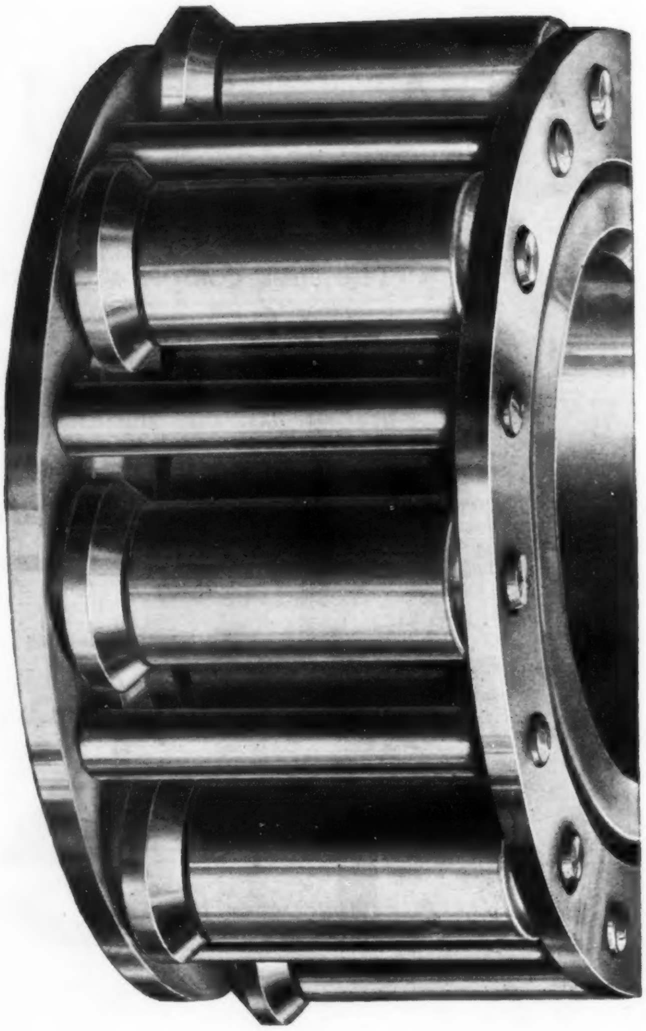
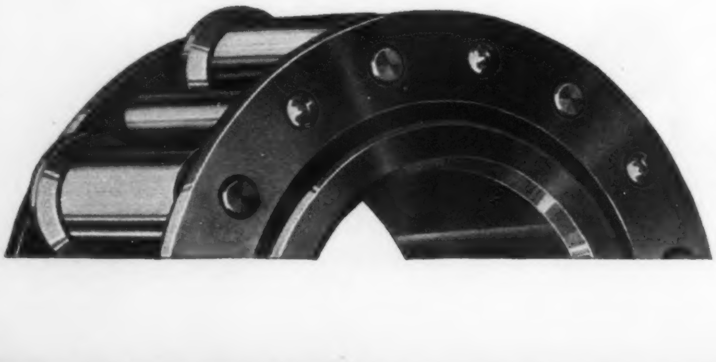

DAHLSTROM
METAL MOULDINGS & SHAPES
DRIP MOULDINGS
HOOK CHANNELS
WINDSHIELD TUBINGS
GLASS CHANNELS
GARNISH MOULDINGS
CUSHION RETAINERS
INSTRUMENT BOARDS
FLOOR BOARD MOULDINGS
Write for Complete Information or Samples of Above Shapes
DAHLSTROM METALLIC DOOR CO.
475 BUFFALO STREET, JAMESTOWN, NEW YORK
Representatives in All Principal Cities
New York Office 25 Broadway
Detroit Office 1331 Dime Bank Bldg.
Chicago Office 19 S. LaSalle St.
Cleveland Office 916 Swetland Bldg.
St. Louis Office 106 N. 3rd. St.
Philadelphia Office 305 Bulletin Bldg.

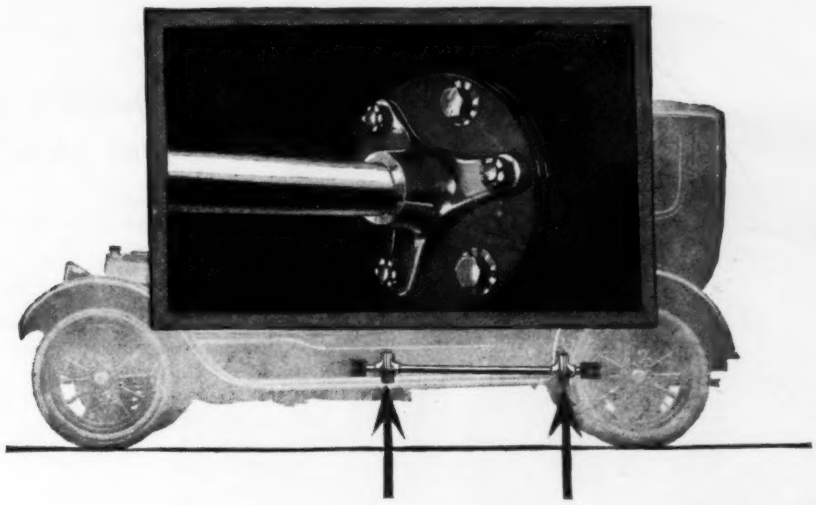

GREATER PRECISION
LESS FRICTION ::
LONGER LIFE ::
ADEQUATE THRUST
CAPACITY
THE FEDERAL BEARINGS CO.,
INC.
Poughkeepsie, N. Y.
Schatz
"UNIVERSAL"
Registered
U.S.Pat.Off.
Annular
BALL BEARING
Use
a BALL bearing











Putting the universal on the list of parts the owner never touches

Can a universal joint run 60,000 miles without lubrication or adjustment?

After a thousand miles metal universal joints fairly cry out for grease and attention. Lubrication of metal joints is ineffective because the rapid spinning motion of the drive-shaft whirls the grease *away from* the joint instead of *into* the wearing parts.

Ordinary *disc* universals, although needing no lubrication, require frequent attention and even replacement because they stretch out of true after a few thousand miles.

The basic patent on the flexible fabric disc universal is the patent on Fanwise Construction. This is a feature of the Thermoid-Hardy Universal Joint.

The diagrams at the right tell graphically exactly what Fanwise Construction means in the strength and wear of the disc, and in its ability to keep the shaft centered and true at all times.

So flexible that it cushions every shock of the road—yet strong enough to withstand a 21,000 pound twist! Capable of going 60,000 miles without adjustment, lubrication, or attention of any kind—yet built to stand the hardest service on the heaviest trucks!

You should have this book—sent free to any engineer or dealer

We have prepared a book, "Universal Joints —Their Use and Misuse," that treats the whole subject from all its angles—the mechanical principles involved, construction, lubrication, processes of manufacture, tests for strength, and records of performance. Send for your copy today.

THERMOID RUBBER COMPANY

Sole American Manufacturers

Factory and Main Offices: Trenton, N. J.

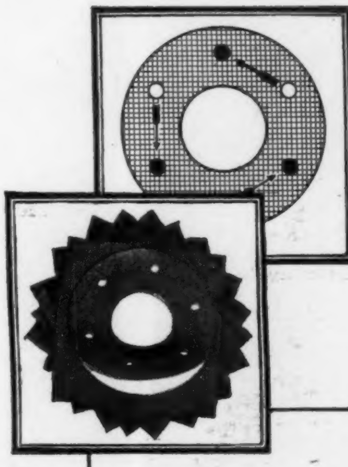
New York	Chicago	Los Angeles	Detroit
Cleveland	Kansas City	Seattle	Atlanta
Boston	London	Paris	Turin

THERMOID-HARDY
UNIVERSAL JOINT

Fanwise Construction for strength
Makers of "Thermoid Hydraulic Compressed Brake Lining" and "Thermoid Crolide Compound Tires"

LIST OF USERS

American British Mfg. Co.
Allis Chalmers Mfg. Co.
Anderson Motor Co.
The Autocar Co.
Available Truck Co.
Barley Motor Car Co. (Roamer)
Crow-Elkhart Motor Corp.
Jas. Cunningham Son & Co.
Dart Truck & Tractor Corp.
The Dauch Mfg. Co.
Diamond T Motor Car Co.
Doane Motor Truck Co
Elgin Motor Car Corp.
Elgin Street Sweeper Co
Fageol Motors Co.
Fifth Ave. Coach Co.
H. H. Franklin Mfg. Co.
Garford Motor Truck Co.
Gramm-BernsteinMotorTruckCo.
Handley Knight
Hawkeye Truck Co.
Hendrickson Motor Truck Co.
Highway Motors Co.
Holt Mfg. Co.
Indiana Truck Co.
International HarvesterCo. of A., Inc.
International Motor Co.
Jackson Motors Corp.
Kelsey Motor Co.
Kentucky Wagon Mfg. Co., Inc.
Kenworthy Motors Corp.
King Motor Car Co.
King Zeitler Co.
Lakewood Eng. Co.
Larrabee-Deyo Motor Truck Co.
Lexington Motor Co.
Locomobile Co
Menominee Motor Truck Co
Mercer Motors Co.
Moreland Motor Truck Co.
McFarlan Motor Co.
Nelson & LeMoon
E. A. Nelson Automobile Co.
Nelson Motor Truck Co.
D. A. Newcomer Co.
O'Connell Motor Truck Co.
Oliver Tractor Co.
Oneida Motor Truck Co.
Packard Motor Car Co.
Parker Motor Truck Co.
Patriot Motors Co.
Reliance Motor Truck Co.
Reo Motor Car Co.
Reynolds Motor Truck Co.
Root & Van Dervoort Eng. Co.
Sanford Motor Truck Co.
Southwark Fdy. & Mach. Co.
Sprague Electric Co.
Stoughton Wagon Co.
Studebaker Corp.
Stutes Mar Tractor Co.
Templar Motors Co.
Tioga Steel & Iron Co.
Towmotor Co.
Traffic Motor Truck Corp.
Transport Truck Co.
Twin City Four Wheel Drive Co., Inc.
United Motors Co.
Walter Motor Truck Co
Ward La France Truck Corp., Inc.
Watson Products Corp.
Geo. D. Whitcomb Co.
Wichita Motors Co.
H. E. Wilcox Motor Co.
J. C. Wilson Co.
Willys-Overland, Inc.
Zeitler & Lamson Truck & Tractor Co.



ABOVE is an ordinary disc, its layers of fabric laid parallel. The three black holes are the driving bolts—the three white ones the driven. Notice that the left hand driving bolt is the only one that can pull in the direction of the strands of cotton. The other two must pull on a bias. This stretches the whole disc out of true, causing vibration and "whipping" of the entire shaft.

In contrast, examine the Thermoid-Hardy patented Fanwise Construction. Notice how the disc is built up with the strands of each layer of fabric running in a different direction. Each sector is of uniform strength and elasticity. Every stress is balanced—

- —the torsional stresses between the bolt holes
- —the centrifugal stresses from the center outward
- —the lateral stresses from the forward and back motion of the shaft.

This means the elimination of "whipping" and vibration. It means that the shaft is held in true on every revolution.

Full Service From Headlights

A 60-mile-an-hour car with 20-mile-an-hour headlights is all right in daytime.

But how about it after dark—the time when the motor makes its best demonstration and the time when the average man has to do a large part of his driving?

Legality of headlights has had much attention because stopping glare is recognized as a necessity. Most cars are equipped with lenses that are legal. But unfortunately most lenses stop the glare by wasting the light. They shoot it into the road too close in front of the car for safe and easy driving. The driver has to sit on the edge of the seat and endure a discomfort that does not exist in daytime.

The average headlights equipped with "legal lenses" do not give road light that is in keeping with the refinements of modern cars. Under such conditions the car that is equipped with exceptional driving light has a valuable selling advantage.

SHALER RoadlighteR

A DIFFERENT KIND OF LENS

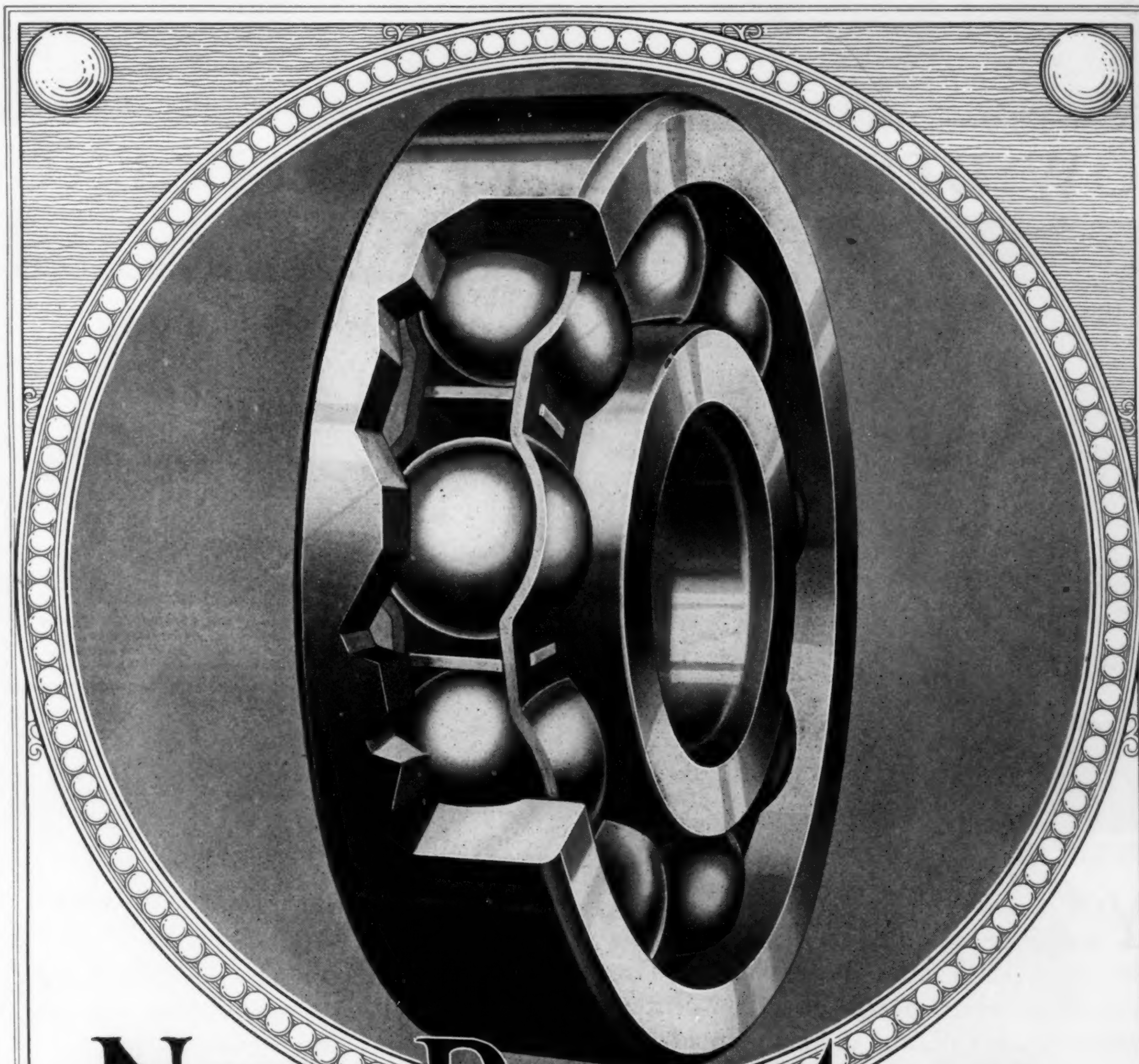
Official State Tests prove that the Shaler Roadlighter gives a more efficient distribution of light on the road than any other lens. They prove that it gives stronger distance light. They prove that it stops glare more effectively.

These are some of the reasons why the Shaler is the most widely known lens on the market today.

No written description can do justice to the remarkable improvement in driving light which the Shaler Roadlighter will give you. You will want to try a pair on your own car to really appreciate the difference between it and lenses that were designed merely for the purpose of stopping glare—many of them so inefficient that when they are used the headlights must be tilted down as much as four feet in a hundred, a tilt that would stop the glare without any lens at all.

Executives of car manufacturers will be supplied with a pair of complimentary Roadlighters on request.

C. A. Shaler Co., 39 Fourth St., Waupun, Wis.



HOW DESIGN SECURES RESILIENCE

A cross section of the Goodyear All-Weather Tread Cushion Tire, the dotted lines showing the shape assumed by the Goodyear patented tread, sidewall and hollow-center designs under pressure

A truck wheel equipped with the new Goodyear All-Weather Tread Cushion Tire

YOU will find the secret of that buoyant resilience which distinguishes the new Goodyear All-Weather Tread Cushion Tire is in its patented design of hollow-center, indented sidewall, and diamond tread.

First look at the design of the hollow center. Seven years ago, Goodyear patented that shape, because under such external pressure as weight of load or sudden impact against obstacles, it "gives" easiest and flexes without strain.

Under these conditions, the rubber is displaced most naturally, the cavity retaining its full size while assuming the shape indicated by the dotted lines. There are no angles formed in which rubber is subjected to breaking stress.

This is the big reason why Goodyear Cushion Tires are the easiest-riding, longest-wearing and most economical.

Further cushioning is provided by the depressions in the sidewall and the wide, deep grooves of the All-Weather Tread. Under compression, the rubber flows most easily and naturally into these hollows.

It is not by chance but by carefully developed design that the cushioning resilience of Goodyear All-Weather Tread Cushion Tires last from the first mile to the last mile of thousands on thousands of miles of low-tire-cost service.

Goodyear Means Good Wear

GOODYEAR

S. A. E. Employment Service

The following announcements are published for the benefit of members of the Society and the convenience of companies in need of men. No charge whatever is made for this service. In the case of items prefixed by an asterisk further information is withheld at the request of the company or individual making the insertion, but written communications bearing the number of such items will be forwarded by the office of the Society. Applications for positions from non-members must be endorsed by a member of the Society.

No announcement will be repeated in these columns unless specific information is at hand that the respective member is available or the position unfilled.

To put available men and employers in touch with each other quickly, this column is supplemented twice weekly by a bulletin giving the latest information with regard to Men and Positions Available. The bulletin will be mailed to members and employers on request.

It is suggested that for quick action in securing men or positions there be specified for publication the name and address, a post-office box number or a general mail delivery address. If applications are confidential, the Society will forward replies through an index number.

For the good of the service members securing or filling positions or companies securing men through these columns are urged to send advices to this effect to the office of the Society promptly.

Considerable time can be saved in securing a position if the following items of information are given in registering with S. A. E. Employment Service.

1. Date
2. Name in full
3. Present mail address
4. Telephone number
5. Present telegraph address
6. Permanent mail address
7. Telephone number
8. Married or single
9. Nationality
10. Age
11. Height
12. Weight
13. State of health
14. Education (Give schools and colleges attended, courses taken and duration of each course)
15. Previous employers (Give names, addresses, term of employment with each, your title and the nature of the work done)
16. Are you employed at present?
17. References (Give names and address of three or four persons not related to you and with whom you have been directly associated)
18. What societies, clubs or associations are you a member of?
19. Salary wanted per week, month, year
20. What general classifications do you wish to be listed under? (List in order of preference. For example: General Manager, Works Manager, Research Engineer, Production Engineer, etc.)
21. Do you wish your name and address published in your announcement?
22. Do you wish to use a post-office box number? (If so, arrange with your postmaster for the use of a box and send the number of the box to us, giving town and state)
23. Is your name to be withheld from publication? (In this case your announcement will be run under an index number and replies will be forwarded through the office of the Society)
24. Prepare copy for insertion in THE JOURNAL and Bulletin. (Make it as complete and as concise as possible)
25. Any preference as to location?
26. When will you be available?

MEN AVAILABLE

0472 PRODUCTION ENGINEER, STOCK SUPERVISOR, PURCHASING AGENT; technical graduate wishes permanent position with going concern; thoroughly familiar with factory organization and control. Residence, Pennsylvania; location, immaterial.

0703 MERCHANDISING MANAGER; sales, advertising; 16 years' automotive experience; capable of building up large profitable business. Residence, New York; location, New York preferred but not essential.

0724 EXECUTIVE; outstanding record; thoroughly experienced in automobile and aviation engines; enduring energy, foresight and ability. Now employed by well-known company. Will consider only reputable organization in New York territory.

(*Continued on p.* 58)

S. A. E. EMPLOYMENT SERVICE

Continued

MEN AVAILABLE

0732 EXECUTIVE ENGINEER; 15 years' experience on automobile designing and production, including both engines and finished cars. Thoroughly experienced in production methods. Residence, Indianapolis; location, Middle West.

0781 GENERAL WORKS OR PRODUCTION MANAGER; superintendent with 15 years' practical experience in the automotive industry. Residence, Michigan; location, Middle West preferred.

0783 PRODUCTION ENGINEER; 5 years' experience with leading companies in production and development work; technical graduate; good references. Available at once. Residence, New York City; location, immaterial.

0794 AUTOMOTIVE ENGINEER; 17 years' experience on passenger cars, trucks, tractors and engines. Recent experience developing heavy-duty air-cooled engines. Residence, New York City; location, immaterial.

0795 ENGINEER having 10 years' experience in the design of high-grade motor cars, wishes position as chief engineer or in experimental and consulting work on aviation engines. Residence, New Jersey; location, Eastern States preferred.

0797 DRAFTSMAN AND DESIGNER; experienced in detail and layout work, purchasing, tool design and airplane drafting. Residence, New York City; location, New York City or vicinity.

0798 SALES ENGINEER; wide acquaintance in Baltimore territory; 13 years' sales, engineering and production experience in automotive and allied lines. Residence, Baltimore; location, Baltimore or vicinity.

0805 EXPERIMENTAL ENGINEER; capable of organizing and directing research and analyzing data and making reports. Also layout work experience. Residence, New Jersey; location, New York City or vicinity.

0806 SALES ENGINEER, DISTRICT, BRANCH OR EXPORT MANAGER; 17 years' experience in automobiles, trucks, engines and accessories, sales, advertising, organization, finance and management. Residence, New York City; location, New York City or vicinity.

0810 SERVICE ENGINEER; 16 years' experience as organizer and efficiency expert in passenger-car and truck service-stations. Also truck factory experience. Residence, New York City; location, immaterial.

0816 ASSISTANT CHIEF OR DESIGNING ENGINEER; technical graduate; 9 years' experience in automobile, truck, engine, and airplane design. College teaching, testing and experimental engineering. Residence, Connecticut; location, immaterial.

0823 DESIGNER; 5 years' experience in engine testing, jigs, fixtures, foundry practice, drafting and production. Residence, New Jersey; location, immaterial.

0827 MOTOR TRANSPORTATION OR RESEARCH ENGINEER; operation manager of motor-transport fleet, manager of chain service-station or superintendent of maintenance for motor-transport fleet, wholesale transportation sales engineer, industrial manager, professor of highway transport. Residence, Massachusetts; location, Pacific coast preferred.

0828 DESIGNING ENGINEER; familiar with latest design in buses and trucks, including 3 years' development work in this line. Residence, Ohio; location, immaterial.

0829 SALES MANAGER OR ENGINEER on automobile transmissions or clutches. Has wide acquaintance with principal purchasing and engineering executives in automobile industry and a successful past record. Residence, New York City; location, Middle West preferred.

0835 SALES ENGINEER OR PURCHASING AGENT; Graduate mechanical engineer with 14 years' experience. An organizer and one who knows the best methods of producing the most profitable connections. Residence, Canada; location, immaterial.

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See announcement at the head of the S. A. E. Employment Service column, p. 56.

S. A. E. EMPLOYMENT SERVICE
Continued

MEN AVAILABLE

0844 PRODUCTION, DESIGNING OR SALES ENGINEER; 9 years' experience; ball bearings; has held positions of assistant chief engineer and chassis engineer. Residence, Toledo; location, immaterial.

0845 CHIEF ENGINEER OR ASSISTANT CHIEF ENGINEER; technical graduate; 14 years' experience in gas engines, automobiles, airplanes, both in design and experimental work. Permanent connection desired. Residence, New York State; location, of secondary importance.

0846 MECHANICAL ENGINEER; 15 years' gas engine experience; development work for ordnance department in connection with motorizing heavy artillery. Has built caterpillar gun mount special war engine and developed truck engine "get-at-able." Residence, New York City; location, eastern states.

0847 DISTRICT MANAGER OR SALES ENGINEER; technical graduate; 17 years experience; successful record on ignition apparatus and body hardware, sales and engineering. Wide acquaintance among automotive manufacturers and body builders. Residence, Cleveland; location, Cleveland territory preferred but not essential.

0848 ASSISTANT ENGINEER OR SUPERINTENDENT; airplane and engine inspector, experienced in checking designs and calculations; has been in charge of testing and inspection departments of prominent motor-vehicle company. Residence, suburb of New York City; location, New York or New Jersey preferred.

0850 BODY ENGINEER AND EXECUTIVE; 12 years with foremost body manufacturers on designs, production, and in executive capacities as chief draftsman, chief engineer, experimental engineer, assistant works manager. Familiar with factory organization, production methods, metal stampings and wood construction. Technical graduate. Residence, Philadelphia; location, immaterial.

0860 CARBURETER ENGINEER with 10 years' experience in the design of automotive gasoline engines who has made a special study of carburetion and recently designed new type of carbureter; has designed, built and conducted tests of experimental engines and is familiar with the design of heavy oil engines of the injection type. Residence, Massachusetts; location, immaterial.

0861 ASSISTANT ENGINEER OR INSPECTOR; 14 years' experience in the production of internal-combustion engines; service manager; superintendent; foreman; 4 years with the Government in charge of testing marine and stationary engines. Residence, Texas; location, immaterial.

0862 EXPERIMENTAL ENGINEER, INSPECTOR; 10 years' experience; electrical inspection, car testing; research work. Residence, Connecticut; location, immaterial.

0865 CHIEF ENGINEER, FACTORY MANAGER with a proved record; for foresight and ability; 12 years' experience on passenger cars, aviation engines, trucks and tractors. Now employed by well-known firm in the automotive industry. Residence, New York City; location, immaterial.

0866 SALES ASSISTANT CHIEF OR CHASSIS ENGINEER; technical graduate; 7 years' experience in passenger car design; charge of experimental work, and design. Residence, St. Louis; location, immaterial.

0867 AUTOMOTIVE ENGINEER; 4 years' experience in designing, drafting, research work and airplane engines. Now with prominent publishing company but wishes change. Residence, New York City; location, New York City or vicinity.

0868 SALES ENGINEER, CHIEF DRAFTSMAN, DESIGNER; technical graduate; 8 years' experience in shops and engineering department of well-known companies on internal-combustion engines, trucks, tractors, automobiles and special and automatic machinery for their production. Residence, Chicago; location, Chicago preferred.

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See announcement at the head of the S. A. E. Employment Service column, p. 56.

S. A. E. EMPLOYMENT SERVICE

Continued

MEN AVAILABLE

0869 ENGINEER. Young man with chassis and engine design experience wishes to associate himself with a live automobile or parts company in engineering or purchasing departments. Residence, Detroit; location, Michigan or Ohio preferred.

0873 PRODUCTION ENGINEER, CHIEF ENGINEER, PURCHASING AGENT; 11 years' practical experience in production and management. Extensive experience abroad; tractors, trucks, sales, consulting and research work. Residence, Connecticut; location, immaterial.

0874 RESEARCH OR PRODUCTION ENGINEER. Graduate mechanical and civil engineer with 25 years' experience as chief engineer or professor of machine design. Residence, New York City; location, New York City or vicinity preferred.

0876 MECHANICAL AND ELECTRICAL ENGINEER; technical graduate with 2 years' experience as plant engineer and 3 years as research and development engineer on pressure gages, safety valves, general brass goods, and carbureters. Residence, Boston; location, Boston preferred but not essential.

0880 RESEARCH ENGINEER; experienced in laboratory design and operation, dynamometer and road testing; the design of instruments to determine the relation of the vehicle to the highway and transmission development with prominent companies in the East. Residence, suburb of New York, location, East preferred.

0881 PRODUCTION MANAGER, RESEARCH ENGINEER; technical education; 18 years' practical experience with passenger cars and commercial vehicles. Capable of handling all engineering or production problems. Successful record. Residence, Detroit; location, immaterial.

0885 CONTRACT OR SALES ENGINEERING REPRESENTATIVE; graduate of Massachusetts Institute of Technology with degree of mechanical engineer; 6 years' experience; 2 years experimental work. Thoroughly experienced in the fabrication of metals and woods. Residence, New Jersey; location, immaterial.

0886 DESIGNING ENGINEER; FACTORY EXECUTIVE; 20 years' experience on passenger cars, trucks, tractors, trailers, Diesel and producer gas engines, truck engines of the two-piston type, experimental work, body and sheet metal layout. Residence, California; location, immaterial.

0887 AUTOMOBILE DESIGNER; 10 years' experience; technical graduate; drafting, layout work. Residence, New York City; location, New York City or vicinity.

0888 AERONAUTICAL ENGINEER; graduate mechanical engineer; 10 years' experience design, shop, production. Research, experimental work on gliders and low-powered, high-speed commercial aircraft. Cost-accountant, expert on transportation costs. Able to take charge of research, design, construction of transportation planes. Residence, New York State; location, vicinity of New York City or Pacific coast.

0889 DESIGNING AND LAYOUT ENGINEER; has had charge of the design and development of isolated lighting plants; 6 years' experience on automotive electrical equipment and magnetic transmissions. Tool design and production work; chief draftsman. Residence, Syracuse; location, immaterial.

0891 SERVICE MANAGER, SALES ENGINEER; unusual training along practical lines for 20 years. Thoroughly understands sales work and retail trade regarding service requirements. Technical assistant to sales manager in handling complaints or developing service information and literature to improve the quality of repair work; chief inspector. Residence, New York City; location, New York City or Detroit.

0893 EXPERIMENTAL ENGINEER. Executive on automotive machine work who is competent to assist in design, tooling and production of steam automotive powerplant would consider starting as foreman of machine shop or a machinist to prove ability. High references. Residence, Mississippi; location, immaterial.

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See announcement at the head of the S. A. E. Employment Service column, p. 56.

S. A. E. EMPLOYMENT SERVICE

Continued

MEN AVAILABLE

0894 MECHANICAL ENGINEER AND DESIGNER. Man with 17 years' experience including 10 years on Diesel oil engines wishes to connect with company building Diesel oil engines for marine, stationary or locomotive purposes. Has designed and built complete lines. Residence, Cleveland; location, immaterial.

0895 DESIGNING AND RESEARCH ENGINEER; 11 years' experience on four and six-cylinder truck and automobile engines. Available now. Residence, Wisconsin; location, Middle West preferred.

0896 SALES ENGINEER wishes to get in touch with companies desiring to market their products in Detroit and vicinity and who require a man having the ability to talk with the engineers. Residence, Toledo; location, Detroit and vicinity.

0897 METALLURGICAL ENGINEER; technical graduate; investigation of production problems; materials, specification, heat-treatment; consulting work on manufacturing and metallurgical problems; stampings, forgings. Residence, New Jersey; location, immaterial.

0902 CHIEF OR ASSISTANT CHIEF ENGINEER. Man now with prominent engine company wishes change; 18 years' experience with well-known companies in layout work, sales, service, and production. Residence, Illinois; location, Ohio, Indiana or Michigan preferred but not essential.

0903 DRAFTSMAN; 12 years' experience in the design and production of gas engines, automobiles and trucks. Executive experience and ability. Available now. Residence, New York City; location, East preferred.

0904 YOUNG ENGINEER Technical graduate wishes a position in design department of company building engines. Residence, New York City; location, New York State preferred.

0905 MECHANICAL AND CHIEF ENGINEER; 15 years' experience on internal-combustion engines for tractors, trucks and agricultural equipment and 3 years general engineering. Residence, Illinois; location, immaterial.

0906 STEAM AUTOMOTIVE ENGINEER possessing organizing and selling ability wishes position with a company about to develop and market a steam automobile. Research and designing experience. Residence, Illinois; location, Middle West.

0907 MECHANICAL ENGINEER; technical graduate with shop, design and production experience on interchangeable parts, transmissions, differentials and tools. Residence, New Jersey; location, immaterial.

0908 FACTORY MANAGER Graduate engineer who is experienced in the management of a force of 7000 men and thoroughly acquainted with organization and uptodate methods wishes to make connection in United States along commercial or manufacturing lines. Residence, Finland.

0911 GRADUATE ENGINEER; 10 years' experience in the design of engines, transmissions, axles and complete cars, and trucks. At present chief engineer of well-known automobile company. Residence, Ohio; location, immaterial.

0912 YOUNG ENGINEER; Graduate of foreign technical school who is experienced in tool designing desires a position as assistant engineer. Residence, New York City; location, New York City or vicinity.

0913 SUPERINTENDENT OR MANAGER; successful organizer with 14 years' experience in handling men mostly in the production of marine and automobile engines; technical graduate who has had practical training in a shop foundry. Residence, Ohio; location, Cleveland or vicinity preferred.

0914 SALES ENGINEER possessing a wide acquaintance among automobile and truck builders and several years successful sales experience wishes to make a connection with a reliable automotive parts manufacturer for representation in Middle West. Residence, Toledo.

0915 ENGINEER DESIGNER; 20 years' experience; technical graduate; specialist in moderate and high-priced passenger-car and truck engines, transmissions and rear-axle design. Residence, Detroit; location, immaterial.

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See announcement at the head of the S. A. E. Employment Service column, p. 56.

S. A. E. EMPLOYMENT SERVICE

Continued

MEN AVAILABLE

0916 SALES ENGINEER for automotive equipment. At present connected with large company covering Mid-West territory. Aggressive, resourceful. Residence, Chicago.

0917 FACTORY MANAGER AND ENGINEER; technical graduate with 22 years' experience in automotive industry; thoroughly familiar with modern foundry practice and competent to handle a large working force and maintain highest standard at lowest cost. Residence, Illinois; location, immaterial.

0918 WORKS MANAGER; technical graduate possessing 4 years' experience in marine engineering and gas engine design and some airplane engine experience is willing to work in different departments to qualify for managing position. Residence, New Jersey; location, East preferred.

0924 SERVICE MANAGER, EXPERIMENTAL ENGINEER OR FACTORY SALES REPRESENTATIVE; 10 years' experience including broad theoretical and practical training in automotive design. Residence, Chicago; location, immaterial.

0925 EXECUTIVE ENGINEER; 14 years' experience in the design and production of motor trucks, machinery and rail-cars. At present chief engineer with well-known company in Canada. Residence, Hamilton, Ont.; location United States preferred.

0926 RESEARCH OR CONSULTING ENGINEER; technical graduate with many years' experience with leading automotive companies; special investigator on engine or automotive problems. Residence, Buffalo; location, immaterial.

0927 AUTOMOTIVE ENGINEER; technically educated man with 10 years' experience in responsible engineering positions with leading companies. Competent to direct research or experimental engineering. Residence, New Jersey; location, immaterial.

0928 SERVICE AND SALES ENGINEER; thoroughly experienced in automobile and truck production; a capable executive who is competent to organize and develop personnel to a high degree of efficiency. College education. Residence, New Jersey; location, immaterial.

0935 SALES MANAGER; exceptional experience; 10 years, in charge of sales and advertising of a prominent automotive parts companies and for past 7 years sales manager of the automotive division of a prominent company. Known to majority of car producers. Good references. Prominent in the trade. Residence, Detroit; location, immaterial.

0936 RESEARCH ENGINEER; technical education; 10 years' research experience on automotives including automobile and marine engines, cars, motor boats and accessories. Residence, New York City; location immaterial.

0937 AUTOMOTIVE ENGINEER with 15 years' experience desires a responsible position. Recent experience has been with farm tractors and gasoline engine driven locomotives in a supervisory capacity. Residence, Ohio.

0941 ASSISTANT TO EXECUTIVE; university graduate with 6 years' experience with motor-car producers. Competent to take charge of service work, purchases and stores stock, assist in engineering, etc. Airplane engine experience; also experimental work. Residence, New York City; location, New York City or vicinity preferred.

0942 CHIEF INSPECTOR, CHIEF DRAFTSMAN OR ASSISTANT ENGINEER; 15 years' experience with prominent automotive companies. Technical graduate. Experimental work. Residence, Detroit; location, Middle West preferred.

0943 PRODUCTION ENGINEER having a record of successful activity with internationally known organizations as a production engineer. Thoroughly experienced in modern production and cost control methods, inspection supervision control and labor management. Highest of references. Residence, New York City; location, Eastern States preferred.

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S. A. E. EMPLOYMENT SERVICE

Continued

MEN AVAILABLE

0944 SALES ENGINEER AND EXECUTIVE; 10 years' experience including 6 years in charge of sales of large die-casting manufacturer. Wide acquaintance among automobile and accessory manufacturers and larger accessory jobbers. Residence, New Jersey; location, immaterial.

0945 EXECUTIVE ENGINEER; organizing ability; over 15 years' experience in service and production. Residence, suburb of New York City; location, immaterial.

0947 TOOL ENGINEER; 10 years' experience; had charge of the design of two complete tanks and two complete tractors for the Government. Residence, Detroit; location, Detroit if possible.

0953 JUNIOR AUTOMOTIVE ENGINEER; experienced as automotive draftsman, tool designer, and experimental engineer. Technical graduate. Residence, vicinity of New York City; location, New York City or suburb preferred.

0954 ENGINEER desires to get in touch with a company that would be interested in the development and sale of a new type of hydraulic brake system. Residence, New Jersey; location, immaterial.

0955 SALES ENGINEER; 20 years' experience as a district sales manager for prominent company manufacturing electrical equipment and anti-friction bearings. Highest references. Available now. Residence, Detroit; location, Middle West preferred.

0956 AUTOMOTIVE ENGINEER; university graduate with 3 years' experience in automobile, truck and tractor engine design, checking and sales work; also a general knowledge of shop production, testing and experimental work. Residence, New York City; location, immaterial.

0957 SUCCESSFUL SALES ENGINEER with broad experience desires to represent manufacturer of high-grade technical product on Pacific coast with headquarters at Los Angeles.

0958 RESEARCH AND PRODUCTION ENGINEER; technical graduate possessing 8 years' experience in tool design. Residence, Cleveland; location, Cleveland or vicinity.

0959 METALLURGICAL ENGINEER; 12 years' experience in technical manufacture, design, management, sales and research applied to increase of production; 5 years as chief metallurgist in leading aircraft plant. Graduate electrical engineer; author of technical articles on metallurgy. Residence, Philadelphia; location, East preferred.

0963 EXECUTIVE; experienced in handling a large group of men on chassis building and automobile pressed parts. Years of experience in general engineering and design. Residence, Massachusett; location, immaterial.

0964 METALLURGICAL ENGINEER; college graduate with excellent technical and practical experience in open-hearth and heat-treating departments. Can handle men. Experienced on large production jobs. Residence, Cleveland; location, Cleveland or vicinity preferred, but not essential.

0965 WORKS MANAGER OR OPERATING ENGINEER; technically trained man possessing 6 years' broad mechanical engineering experience and successful in handling men. Residence, St. Louis; location, immaterial.

0966 ASSISTANT ENGINEER OR CHIEF DRAFTSMAN; passenger-car and truck experience in both body and chassis work. Available at once. Residence, New York State; location, East preferred.

0970 SALES PROMOTION ENGINEER; technical graduate and Society member; 13 years' experience in engineering, publicity and sales; including 5 years with prominent parts manufacturer and 3 years, as successful sales engineer. Residence, Springfield, Mass.; location, Central New England preferred but not essential.

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See announcement at the head of the S. A. E. Employment Service column, p. 56.

S. A. E. EMPLOYMENT SERVICE

Continued

MEN AVAILABLE

0971 METALLURGICAL ENGINEER; 5 years' experience as factory manager and 3 years as sales engineer. Complete details as to ability, references, etc., will be given to companies in need of a capable and successful man with these qualifications. Residence, Cleveland.

0972 ASSISTANT GENERAL MANAGER, WORKS OR SALES MANAGER; 14 years' experience in prominent automobile factories and related industries. Dependable result producer. Has held positions as superintendent, department head, director of purchases, chief engineer and factory manager. Residence, Detroit.

0973 CHIEF ENGINEER; chief draftsman; consultant; long experience on buildings, plant and machinery. Familiar with body and chassis. Residence, Cleveland; location, Pacific coast preferred but not essential.

0974 AUTOMOTIVE ENGINEER OR DRAFTSMAN; technical graduate; over 10 years' satisfactory experimental work on trucks, tractors and passenger cars. Residence, Syracuse: location, immaterial.

0975 WORKS MANAGER AND ENGINEERING EXECUTIVE; engineering graduate with 13 years' experience in factory management and as engineering executive. Cost reduction a specialty. Available at once. Residence, New York City; location, Metropolitan Section preferred.

0976 ENGINEER Technical graduate with 3 years' general construction and engineering experience as an airplane designer and engineer desires a designing, experimental or research position. Residence, New York City; location, immaterial.

0977 BODY ENGINEER OR DRAFTSMAN; technical graduate; 9 years' experience high class automobile bodies. Residence, New York City; location, immaterial.

0978 LAYOUT DRAFTSMAN with technical education; 3 years' experience on frames, axles and general chassis layout work and 2 years' general drafting on automobile engines. Residence, New Jersey; location, immaterial.

POSITIONS AVAILABLE

245 SALESMEN with sufficient engineering ability so that they are familiar with internal-combustion engine detail and can talk with repair shop men on subjects in which they are interested and in which the company is interested, particularly pistons, cylinders and the packing of pistons. Considerable territory open for men having this ability and several branches open where sales managers are needed. Location, New York City.

266 WHOLESALE AUTOMOBILE SALESMEN. One or two good men to work under district manager, covering several states in Chicago territory.

270 SALESMEN and district sales managers are needed by piston-ring company in New York City.

308 MECHANICAL AND PRODUCTION ENGINEER who is experienced on taper roller bearings, preferably man who has been employed by the Timken Roller Bearing Co., is wanted immediately. Must have wide experience in all details and will make his headquarters in New York City.

384 HIGH-GRADE SALES REPRESENTATIVES Two men with mechanical knowledge to act as special sales representatives in assisting branch managers analyze and promote the sale of motor trucks to oil and gasoline, packing, wholesale grocery and food products industries. Must have a thorough knowledge of and wide acquaintance with executives of one of the above industries and travel extensively. Make application by letter giving personal characteristics, business experience in detail, salary expected and date available. Headquarters, Cleveland.

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S. A. E. EMPLOYMENT SERVICE
Continued

POSITIONS AVAILABLE

385 PRACTICAL MAN who understands the magnetizing of steel for experimental work from the theoretical side also is wanted by a well-known manufacturing company. Experimental work will last about 1 year, but will lead to excellent position. Location, New Rochelle, N. Y.

394 TRUCK SALESMAN is desired by company in Brooklyn.

396 METALLURGIST Man over 35 years of age is wanted by a company located in New York State. Must have at least 10 years' experience and be thoroughly versed in the treating of alloy steels, etc. Man with experience on a large production job preferred.

397 CHIEF INSPECTOR wanted by a company in New York State. An engineer who is able to organize an inspection department and will have under his supervision from 100 to 150 inspectors. This company will manufacture all of its own units including engines, axles, transmissions, steering devices, etc., and wants a man for this department who is diplomatic and thoroughly understands the latest inspection methods and how to handle men. Appointee will be under the engineering department's supervision, but will come in contact practically all of the time with men in the production department.

402 ELECTRICAL REPAIR MAN for general repairing of automobile electrical equipment and service work. Location, North Carolina.

409 TRACER for engine design department of prominent airplane company in New Jersey. Phone for interview.

411 MACHINISTS, INSPECTORS AND ASSEMBLYMEN Permanent positions are open for first-class men. Production for 1923 is expected to reach over 200 cars of the very highest quality. Communicate with W. A. Doble, general manager, Doble Steam Motors, 714 Harrison Street, San Francisco.

414 MAN is wanted by company in Cleveland to handle the marketing of a car that is built to cater to that class of trade desiring a high-grade closed car. Only men with experience handling a car along similar lines need apply.

422 ENGINEERS Positions in central office engineering division are open for men with college training in engineering or the physical sciences. Practical telephone experience may take the place of college training. Location, Chicago.

423 DRAFTSMEN who have had technical high school training and from 2 to 4 years' drafting experience, preferably in the power or telephone fields. Location, Chicago.

424 SALES MANAGER Man with sales experience on automotive accessories is wanted for New York territory. Good proposition for the right man. Technical knowledge preferred, but sales ability would do. Headquarters, Detroit.

425 SALESMEN wanted immediately, covering automobile jobbers and dealers, to sell horn on commission basis. Exclusive territory to a producer. Location, New York City.

426 ASSEMBLY FOREMAN wanted by prominent steam car company in San Francisco.

429 RESEARCH ENGINEER wanted by machine company in Worcester.

432 CONSULTING ENGINEER is wanted by prominent company in Middle West.

433 DETAIL DRAFTSMAN wanted by company in New York City. Must be thoroughly familiar with cars and engines and a university graduate.

434 MAN to assist truck sales manager. Good truck experience. Location, Ohio.

*435 ENGINEER with experience in manufacturing and designing a motor-driven electric horn wanted by company at Milwaukee. In making application, state experience, age, previous employment and salary expected.

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See announcement at the head of the S. A. E. Employment Service column, p. 56.

S. A. E. EMPLOYMENT SERVICE

Concluded

POSITIONS AVAILABLE

438 TRACERS OR DETAIL DRAFTSMEN. Two men with experience in airplane design work are wanted by airplane company in New Jersey.

439 CHEMIST by a company in Pennsylvania will soon be needed. Also a few all around rubber men who understand the manufacture of rubber toy balloons, and drug sundries.

443 DRAFTSMAN experienced in mechanical work. Permanent position. Salary about $40 per week. Wanted immediately. Location, New Rochelle.

444 BODY ENGINEER wanted by motor-car company in New Jersey.

445 AUTOMOTIVE RESEARCH WORKERS. Prominent company in New York City wishes two technical graduates.

446 MEN who have a knowledge of internal-combustion engines are wanted by prominent shipbuilding company in Pennsylvania.

*447 PRODUCTION AND WORKS MANAGER to take complete charge of plant at Brooklyn, N. Y., employing about 350 men and manufacturing automobile hardware, die-castings and stampings. Must be a mechanical engineer and thoroughly experienced in the production of small accurate parts in large quantities as well as a capable executive, experienced in uptodate manufacturing methods and factory cost systems and able to organize the various departments and obtain the cooperation of the employes. A man with extensive experience in a similar capacity is what is required. Write, giving full detailed information, experience, references, age, and salary expected.

See announcement at the head of the S. A. E. Employment Service column, p. 56.

Have We Your Correct Address?

The New York Office is just as anxious as the individual members that they receive THE JOURNAL and other communications promptly.

This result cannot be achieved unless

Members notify the office whenever they make a change in their business connection or their mail address or both.

Members who have been in the service of the Government either as civilians or in the Army or Navy let us know when they leave the service and also when they re-enter commercial fields.

Your cooperation is necessary and will be greatly appreciated.

May We Have It?

SOCIETY OF AUTOMOTIVE ENGINEERS, Inc.

SIMPLE

One of the outstanding features of Arrow Grip Non-Skid Chains is the ease and rapidity with which they may be attached.

Two parts constitute the complete Arrow Grip unit: clamp and chain. The clamp, of rust proofed malleable iron, can remain permanently on the spoke; the chain, of welded steel, is attached instantly, when required.

As effective as they are simple. Make Arrow Grips standard equipment on your trucks and guarantee full performance regardless of weather or road conditions.

Correspondence from Automotive Engineers Invited

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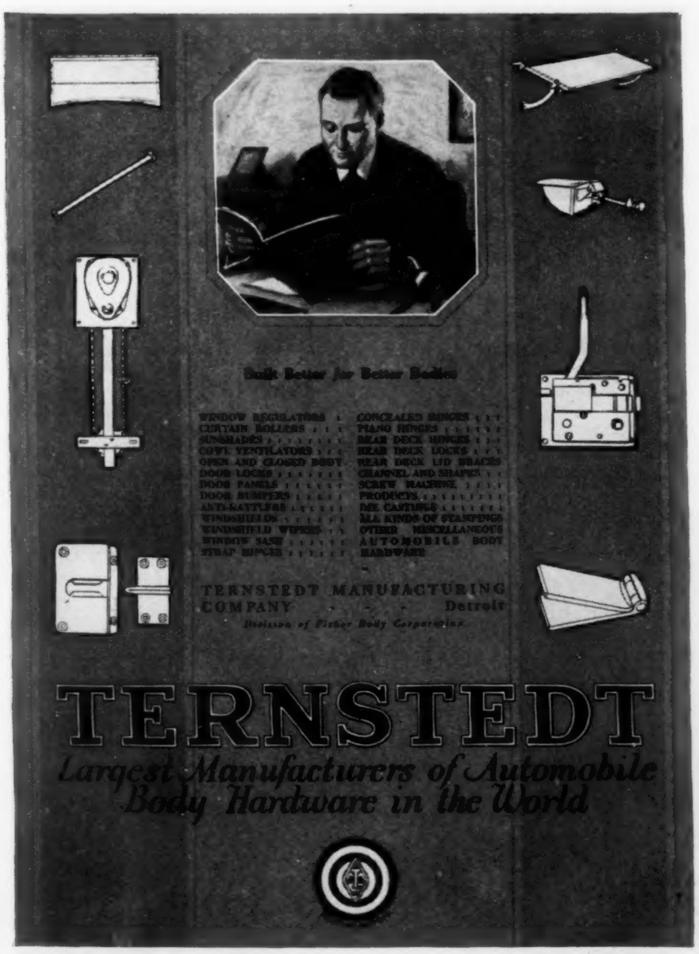

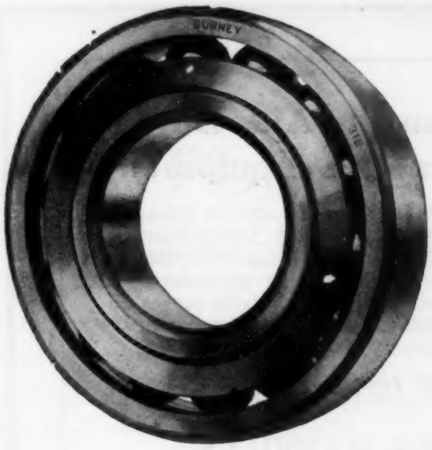

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MODERN mechanics require some startling speeds. The only bearing which will serve speed requirements safely and uninterruptedly is the ball bearing.

Gurney Ball Bearings are serving in machines of all degrees of speed—carrying light or heavy, slow or fast loads safely and uninterruptedly.

Let Gurney engineers assist in securing safer, simpler, more efficient bearings for your machines.

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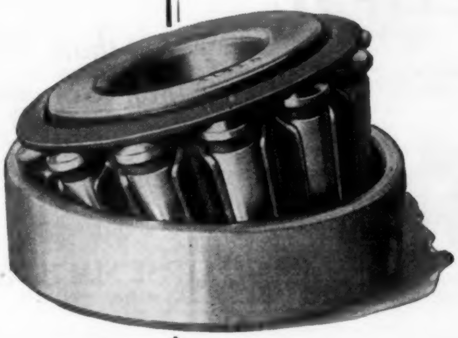
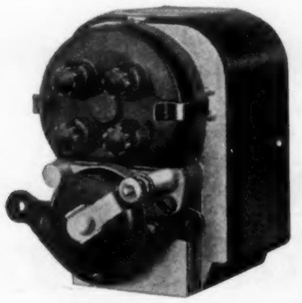
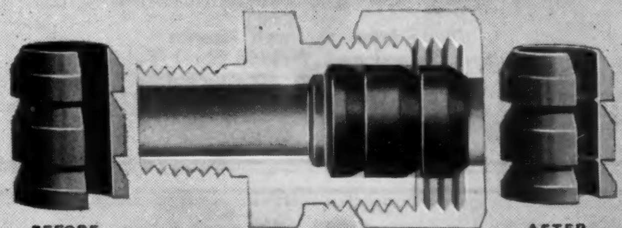




MEMBERS' PROFESSIONAL CARDS



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Vanadium Corporation of America

Alloys, Cupro-Vanadium
Vanadium Corporation of America

Alloys, Ferro-Molybdenum
Vanadium Corporation of America

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Vanadium Corporation of America

Alloys, Ferro-Vanadium
Vanadium Corporation of America

Alloys, Steel (See Steels)

Aluminum Alloys, D104
*Hoyt Metal Co.

Ammeters, B12
*Nagel Electric Co., W. G.
*Sterling Mfg. Co.
Westinghouse Electric & Mfg. Co.

Apparatus, Charging, Electric Vehicle
Westinghouse Electric & Mfg. Co.

Apparatus, Laboratory
Olsen Testing Machine Co., Tinius

Axles, Front, Motor-Truck, F1b
*Eaton Axle Co.
Sheldon Axle & Spring Co.

Axles, Front, Passenger-Car
Eaton Axle Co.
Salisbury Axle Co.

Axles, Rear, Motor-Truck
Eaton Axle Co.
Sheldon Axle & Spring Co.

Axles, Rear, Passenger-Car
Eaton Axle Co.
Salisbury Axle Co.

Axles, Trailer
Salisbury Axle Co.

Babbitt, D103
*Franklin Die-Casting Corporation
*Hoyt Metal Co.
*Light Mfg. & Foundry Co.
*Muzzy-Lyon Co.

Balls, Brass, Bronze, Monel Metal, Aluminum
Hoover Steel Ball Co.

Balls, Hollow Bronze and Brass
Hoover Steel Ball Co.

Balls, Steel
Hoover Steel Ball Co.

Bars, Boring
Williams & Co., J. H.

Bars, Bronze
Bunting Brass & Bronze Co.
Mueller Metals Co.

Batteries, Storage, B23
*Marko Storage Battery Co.
*Willard Storage Battery Co.

Bearings, Babbitt and Aluminum
Bunting Brass & Bronze Co.
Doehler Die-Casting Co.
Franklin Die-Casting Corporation

Bearings, Babbitt and Bronze
Bunting Brass & Bronze Co.
Doehler Die-Casting Co.
Hoyt Metal Co.
Mueller Metals Co.
Muzzy-Lyon Co.

Bearings, Ball, Angular Contact Type, C33 to C33e
*Bearings Co. of America
*Fafnir Bearing Co.
*Gurney Ball Bearing Co.
*New Departure Mfg. Co.
*U. S. Ball Bearing Mfg. Co.
*S. K. F. Industries, Inc.

Bearings, Ball, Annular, Extra Small Series, C33
*Fafnir Bearing Co.
*New Departure Mfg. Co.
*S. K. F. Industries, Inc.
*U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Annular, Extra Large, Light and Medium Series, C27 and C29
*Fafnir Bearing Co.
*Gurney Ball Bearing Co.
*S. K. F. Industries, Inc.
*U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Annular, Light, Medium and Heavy Series, C26, C28 and C30
*Fafnir Bearing Co.
*Federal Bearings Co., Inc.
*Gurney Ball Bearing Co.
*New Departure Mfg. Co.
*Norma Co. of America
*S. K. F. Industries, Inc.
*Standard Steel & Bearings, Inc.
*U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Annular, Separable (Open) Type, C32
*Fafnir Bearing Co.
*New Departure Mfg. Co.
*Norma Co. of America
*S. K. F. Industries, Inc.

Bearings, Ball, Annular, Wide Type, C31
*Brown-Lipe Gear Co.
*Fafnir Bearing Co.
*New Departure Mfg. Co.
*S. K. F. Industries, Inc.
*Standard Steel & Bearings, Inc.
*U. S. Ball Bearing Mfg. Co.

Bearings, Bronze
Hoyt Metal Co.
Mueller Metal Co.
Muzzy-Lyon Co.

Bearings, Thrust, Ball, Clutch Release Type, C39
*Bantam Ball Bearing Co.
*Bearings Co. of America
*Fafnir Bearing Co.
*Norma Co. of America
*Standard Steel & Bearings Co.
*U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Thrust, Single-Direction, Flat-Face Type, C35 and C36
*Bantam Ball Bearing Co.
*Bearings Co. of America
*Fafnir Bearing Co.
*Norma Co. of America
*U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Thrust, Single-Direction, Self-Aligning Type, C37 and C38
*Bantam Ball Bearing Co.
*Bearings Co. of America
*Fafnir Bearing Co.
*Norma Co. of America
*U. S. Ball Bearing Mfg. Co.

Bearings, Ball, Thrust, Steering Knuckle Type, C34
*Bantam Ball Bearing Co.
*Bearings Co. of America
*Fafnir Bearing Co.
*Norma Co. of America
*U. S. Ball Bearing Mfg. Co.

Bearings, Roller, Inch-Type
Timken Roller Bearing Co.

Bearings, Roller, Metric-Type, C43 and C44
*Bock Bearing Co.
Bower Roller Bearing Co.
*Norma Co. of America

Blanks, Gear
Canton Drop Forging & Mfg. Co.
Central Steel Co.
Link-Belt Co.
Park Drop Forge Co.
Standard Gauge Steel Co.
Union Switch & Signal Co.

Boards, Floor and Toe
Parish Mfg. Corporation

Bodies, Passenger Car
Baker R & L Co.

Bodies, Motor Truck Dump
Mansfield Steel Corporation

Boilers, Steam, Automotive
Stumpf Una-Flow Engine Co., Inc.

Bolts, Carriage
Columbus Bolt Works Co.

Bolts, Eye
Williams & Co., J. H.

Bolts, Fender
Columbus Bolt Works Co.

Bolts, Spring Shackle
Bowen Products Corporation

Bolts, Step
Columbus Bolt Works Co.

Brackets, Fender
Parish Mfg. Corporation
Smith Corporation, A. O.

Brackets, Lamp
Brewer-Titchener Corporation

Brackets, License-Plate
Brewer-Titchener Corporation

Brackets, Running-Board, H23
Crosby Co.
Parish Mfg. Corporation
Smith Corporation, A. O.

Brake-Drums
Crosby Co.
Parish Mfg. Corporation
Smith Corporation, A. O.

Brass, Laminated
Laminated Shim Co., Inc.

Breakers, Circuit
Dayton Engineering Laboratories Co.

Broaches, 4-Spline, C16
*Lapointe Co., J. N.

Broaches, 6-Spline, C18
*Lapointe Co., J. N.

Broaches, 10-Spline, C20
*Lapointe Co., J. N.

Broaches, 16-Spline, C22
*Lapointe Co., J. N.

Broaches, Keyway
Lapointe Co., J. N.

Bronze Alloys, D108
*Hoyt Metal Co.

Bulbs, Incandescent Lamp, B3
Westinghouse Electric & Mfg. Co.

Bumpers, Motor Truck
Mansfield Steel Corporation

Bumpers, Spring
Thermoid Rubber Co.

Bushings, Babbitt
Muzzy-Lyon Co.

Bushings, Bronze
Bunting Brass & Bronze Co.
Hoyt Metal Co.
Mueller Metals Co.
Muzzy-Lyon Co.

Buttons, Electric Push
General Phonograph Mfg. Co.

Cable, Insulated, B33
Kerite Insulated Wire & Cable Co.
*Packard Electric Co.

Camshafts
Canton Drop Forging & Mfg. Co.
Jackson Motor Shaft Co.
Muskegon Motor Specialties Co.
Park Drop Forge Co.
Wyman-Gordon Co.

Caps, Hub
Crosby Co.

Caps, Radiator and Tank, C58a
*American Insulator Corporation

Carbureters, Cast Iron, A8
*Byrne, Kingston & Co.
*Carter Carburetor Corporation
Zenith Carburetor Co.

Carbureters, Motorcycle
Carter Carburetor Corporation
Zenith Carburetor Co.

Carbureters, A8
*Byrne, Kingston & Co.
*Carter Carburetor Corporation
Zenith Carburetor Co.

Cast Brass Alloys, D106
*Hoyt Metal Co.

Castings, Aluminum**
*Doehler Die-Casting Co.
*Franklin Die-Casting Corporation
Hoyt Metal Co.
*Light Mfg. & Foundry Co.

Castings, Brass**
*Doehler Die-Casting Co.
*Franklin Die-Casting Corporation
*Light Mfg. & Foundry Co.
Mueller Metals Co.
*Scovill Mfg. Co

Castings, Bronze**
*Doehler Die-Casting Co.
*Franklin Die-Casting Corporation
Hoyt Metal Co.
*Light Mfg. & Foundry Co.
Mueller Metals Co.

Castings, Die**
Doehler Die-Casting Co.
*Franklin Die-Casting Corporation
Hoyt Metal Co.
*Light Mfg. & Foundry Co.
Mueller Metals Co.
Saal Co., H. G.

Castings, Grey Iron
Link-Belt Co.

Castings, Malleable Iron, D9
*Eberhard Mfg. Co.
*Frazer & Jones Co.
*Link-Belt Co.

Castings, Steel, D7
Link-Belt Co.

Chains, Block
Link-Belt Co.
Morse Chain Co.
Whitney Mfg. Co.

Chains, Roller, E3
*Link-Belt Co.
*Whitney Mfg. Co.

Chains, Silent, E2
*Link-Belt Co.
*Morse Chain Co.
Whitney Mfg. Co.

Chains, Tire, Motor-Truck
Arrow Grip Mfg. Co., Inc.

Channels, Window Glass
Dahlstrom Metallic Door Co.

Clamps, Hose, C51
Schrader's Son, Inc., A.

Clamps, Machinists'
Eberhard Mfg. Co.
Williams, J. H., & Co.

Cleaners, Windshield
Folberth Auto Specialty Co.

Clips, Spring, H3
Columbus Bolt Works Co.

Clutches, Engine **
*Brown-Lipe Gear Co.

Clutches, Power Transmission
Link-Belt Co.

Coils, Electrical Equipment
Acme Wire Co.
Dayton Engineering Laboratories Co.

Conduit, Flexible, C52
*Titeflex Metal Hose Corporation

Condensation Products
Bakelite Corporation
Condensite Co. of America
General Bakelite Co.
Redmanol Chemical Products Co.
Saal Co., H. G.

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EXPLANATION OF SYMBOLS

Parts and materials followed by key numbers have been standardized by the S. A. E. The numbers refer to S. A. E. HANDBOOK data sheets on which each standard is published.

*Companies whose names are preceded by an asterisk supply the parts or materials under which the company is listed as conforming with the S. A. E. Standard referred to.

**Parts and Materials followed by two asterisks indicate that two or more S. A. E. Standards are applicable. Information as to standards incorporated should be obtained from the manufacturer.

The addresses of companies listed in this index can be obtained from their current advertisements indexed on page 94.

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INDEX TO ADVERTISERS' PRODUCTS

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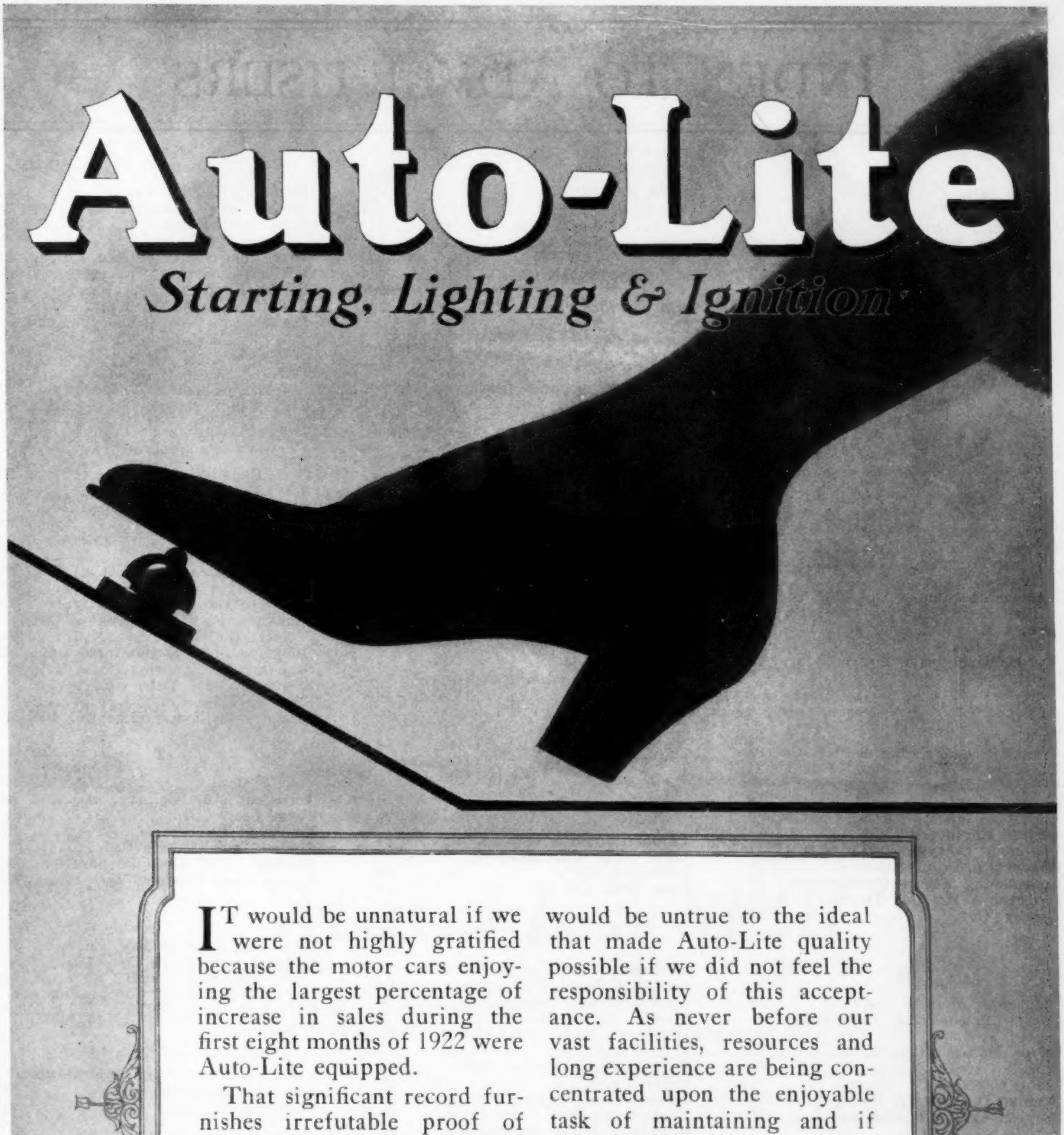
Auto-Lite
Starting, Lighting & Ignition
IT would be unnatural if we were not highly gratified because the motor cars enjoying the largest percentage of increase in sales during the first eight months of 1922 were Auto-Lite equipped.
That significant record furnishes irrefutable proof of Auto-Lite excellence, and we would be untrue to the ideal that made Auto-Lite quality possible if we did not feel the responsibility of this acceptance. As never before our vast facilities, resources and long experience are being concentrated upon the enjoyable task of maintaining and if possible excelling our record.
THE ELECTRIC AUTO-LITE COMPANY
Offices and Works: TOLEDO, OHIO
Detroit Sales Office: 1309 KRESGE BLDG.

INDEX TO ADVERTISERS

An index to advertisers' products is given on pages 88, 90 and 92